INSTRUCTIONS

IN THE USE OF

METEOROLOGICAL INSTRUMENTS.

Compiled by Direction of the Meteorological Committee,

BY

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PREFACE.

THE subjoined Instructions have been prepared by direction of the Meteorological Committee, inasmuch as the "Instructions for taking Meteorological Observations," by Sir H. James, F.R.S., of which the last edition appeared in 1861, are now entirely out of print.

It has been endeavoured to embody in the present compilation allusions to the most important points which would come under the notice of a meteorological observer at an ordinary station.

The tables in the Appendix are those which are most important for use in connection with observations of Pressure, Temperature, and Rainfall, and for the conversion of data published in Foreign measures to English equivalents, and *vice versâ*.

The tables for reduction of the Barometer to sea-level, for the readings of 30 inches and 27 inches respectively, have been recalculated and extended, so as to refer to elevations as far as 1,500 feet.

I have to express my sincerest acknowledgments to many of my friends who have not shunned the trouble of reading and minutely criticizing the work, and who have, from time to time, suggested important improvements.

It cannot be expected but that exception may be taken to some of the statements made and regulations proposed; but it is hoped that these Instructions may have some tendency towards the attainment of, or, at least, an approximation to, that uniformity in methods of meteorological observation, the absence of which is universally felt and regretted.

ROBERT H. SCOTT.

Meteorological Office,
May 7, 1875.

APPENDIX.

INTRODUCTION.

In presenting these "Instructions" to the public it may be well to say a few words by way of introduction, on the subject of observations in general, and on the conditions requisite to constitute a good observing station.

The Vienna Congress has recognised three classes of observing stations:—

A Station of the *First Order* is an observatory in which, without the collection of observations from other stations, meteorological observations are conducted on a great scale, *i.e.*, either by hourly readings or by the use of self-recording instruments.

Stations of the *Second Order* are those where complete and regular observations of the usual meteorological elements, viz., pressure, temperature and humidity of the air, wind, cloud, rain, and hydrometeors (p. 69), &c., are conducted, but with less frequency than at the stations above mentioned.

Stations of the *Third Order* are those where only some of these elements are observed.

It is of course out of the question for a private observer, of ordinary means, to attempt to establish a station of the First Order; and inasmuch as the following Instructions are mainly destined for the use of observers at stations of the Second and Third Orders, it is not purposed to enter into details on the subject of self-recording instruments, or the other requirements of a first-class observatory.

At the other classes of stations the observations are taken by the eye, and to these it is wished to direct especial attention.

At stations of the Second Order the observations are to be made *at least* twice a day at homonymous* hours, for which 9 a.m. and 9 p.m. (local time) have been chosen by a large majority of the volunteer observers who have been consulted within the United Kingdom. Additional observations should, however, be taken at other hours, when convenient, especially during unsettled weather.

At stations of the Third Order, observations are made with less frequency and less completeness than at those of the Second Order; but the observations must be taken at least once daily, and these stations must have properly verified instruments for all the observations which are taken, and the same regularity and punctuality are required in observing as in those of the Second Order.

In fact, observations taken carelessly or with instruments which have not been duly verified by comparison with known standards are utterly useless, while those taken only occasionally are scarcely of any value for scientific purposes.

Under the head of each instrument will be found the necessary requirements as to its construction, verification, &c.

As to the observers, the great qualities which are looked for are a knowledge of the instruments used, accuracy, regularity, and honesty.

As regards knowledge of the instruments—the observer should be familiar with their management, and should know how to apply the respective corrections.

As regards accuracy—the degree of minuteness to which each instrument is to be read will be found noticed in its proper place.

As to regularity—all the observations should be made punctually at the hours fixed for observation. If from any cause an observation is taken either too early or too late, the precise time at which it was taken should be entered in the register; and if the observations are taken by a substitute or assistant, the initials of the actual observer ought to be set down.

Lastly, as regards honesty—if an observation has been omitted, the space for it should be left blank, and a note should be added in the "Remark" column stating

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* By "homonymous" hours are meant hours of the same name, *e.g.*, 8 and 8, 9 and 9, etc.

the reason of the omission. No estimated reading, however obtained, should on any account be inserted.

The requirements as to situation for a meteorological station are that the positions designated for the thermometers and rain gauge shall be perfectly open on all sides. As regards the thermometer screen, there should be no chance of the shadow of trees or buildings falling on it for any long period during the day, or of reflected or radiated heat affecting it.

As to the rain gauge, it should be so placed as not to be sheltered from wind or exposed to eddies, either of which conditions will influence the amount of rain falling into the gauge.

As regards the observations of wind the matter is much more serious. The anemometer must of course be placed in an open space; but if there be trees near, as, *e.g.*, in a park, or if the ground be undulating, the observations of the wind will be seriously affected, as well in direction as in velocity. In such cases money spent on a costly anemometer will be, to a great extent, wasted.

A list of some books of reference on Meteorology will be found at p. 112.

As regards meteorological co-operation in general, the words of the Report of the Committee of Physics and Meteorology of the Royal Society, published in 1840, are as true now as they were 35 years ago, when first penned :—

" After maturely considering the subject, they do not " presume to anticipate that what they may suggest " will not be liable to objections, for their object will " be to include within their compass many excellent " series of observations which are already in progress, " rather than to propose a degree of theoretical perfec- " tion, the attainment of which the present state of the " science may not perhaps admit of. Systematic co- " operation is the essential point to which at present " everything else should be sacrificed; and co-operation " on almost any plan would most certainly be followed " by more beneficial results than any number of inde- " pendent observations, however perfect they might be " in themselves."

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"The Committee are not without hopes that amateurs "of science may be induced to conform to these suggestions, even at the temporary sacrifice of their own "views and convenience; for no one can reflect on the "immense amount of labour which is now rendered "useless for want of the requisite uniformity and precision, without being convinced of the necessity for "remedying an evil which has already been of too long "standing, and continues to be a reproach to science. "Many, of course, will not have it in their power to "fill up the plan in all its details; but they will contribute greatly to forward the design, if, in such observations as they may find it convenient to make, they "strictly comply with the rules proposed."

THE BAROMETER.

General Description of the Instrument.

Construction of the Instrument.—The barometer, as usually constructed, consists of a tube of glass, about 34 inches in length, closed at one end, filled with mercury, and placed vertically with the open end dipping into a cup containing mercury, which is commonly called the cistern. The mercury should be pure, of the specific gravity of 13·594. The mercury does not entirely fill the tube so placed, but, according to the changes of atmospherical pressure, occupies at the level of the sea* from 31 to 27 inches of the tube, measured above the mercury in the cistern. The space above the mercury in a properly filled barometer tube contains nothing but a little of the vapour of mercury. It is called the Torricellian vacuum, from the name of the Italian physicist who invented the barometer.

Barometer scales.

As the mercury in the tube balances the pressure of the atmosphere, it is obvious that it must rise with increased atmospheric pressure and fall with diminished pressure, so that by noting on a linear scale the length of the column, we may *measure* the *weight* of the atmosphere. Such a scale is commonly divided into inches or millimetres, or any other recognised division of length. Tables for the conversion of readings given according to any of the usual scales to the English scale, and *vice versâ*, will be found in Appendix I., Tables III., IV., and V.

It has just been said that the length of the column must be measured from the level of the mercury in the cistern; but it is obvious that during the changes which take place in the length of the column, the mercury which leaves the tube must enter the cistern, or *vice versâ*; hence the level of the mercury in the cistern undergoes changes related to those of the column. In measuring the length of the column we must therefore take into consideration these changes of level in the cistern, and this necessity has led to various constructions of the latter, as will be explained further on. The cistern need not be covered; but, in order to render the instrument portable, it is usually closed in such a way as to prevent the escape of the mercury, while admitting of its being affected by changes in the pressure of the atmosphere, and is firmly cemented to the tube. The whole is then supported by a case.

Material for cases.

There is much variety in the form, though less in the material, of barometer cases. Brass is considered the best material, because its coefficient of expansion by heat is well known; and this is very important, as the tables for correcting barometer readings for

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* The reason for saying "at the level of the sea" will be explained at p. 31.

Material for cases.

temperature, founded upon the coefficients of expansion of mercury, glass, and brass, always give identical results with such barometers, although the nature of the alloy forming the cases may not in all instances be exactly similar.

Barometers are also cased in various woods, but in different, and even in similar, species of wood, the expansive coefficient is not the same, nor is it constant for the same specimen, as wood is affected by moisture as well as temperature. A reduction table has been calculated, founded on an average of various determinations of the expansive coefficients of certain woods, such as oak, walnut, and mahogany, but it cannot be relied upon for accurate results, like that for brass. Barometers in wood, however well made, must always be inferior in accuracy to those mounted in brass, and for this reason readings from such instruments are of little value for scientific purposes.

Material for scales.

The scale, or the greater part of it, is commonly measured along the case; but if a scale be applied which is quite independent of the case, then, of course, the reduction for temperature would depend upon the material of the scale, and not upon that of the case.

The practice is to divide not the whole length of the scale, but only the part usually required; viz., that from 27 to 32 inches, unless the barometer be required for use at great heights above the sea (p. 31), in which case the graduation must be carried much lower. This portion may actually be engraved on ivory, porcelain, or enamel, and fixed in its proper position, but if the case which bears it be brass the entire scale is considered to be on brass, and if the case be wood the scale is considered to be on wood. Such a construction of barometers is, however, utterly unsuitable for instruments of any value.

Cistern level.

The change of level of the mercury in the cistern may be compensated for (1) by a so-called *capacity correction;* (2) by a pliable cistern base; (3) by a contracted scale; or (4) by dispensing with the use of a cistern altogether, and employing for the barometer a tube turned up at the open end in a **U** shape.

The first method must be resorted to when the cistern is entirely covered up, and a scale of standard inches is engraved on the case. The mode of applying the capacity correction is explained at p. 29.

Fortin's method.

By the second method, the necessity for the capacity correction is avoided by a peculiar construction of cistern invented by Fortin, after whom such barometers have been named. The scale is engraved to show true inches. This construction of cistern is best adapted for high class or standard barometers, and will be fully explained when we come to treat of this class of barometers (p. 18).

Contraction of scale.

The third plan was adopted by the Kew Committee of the British Association in 1854, and by means of it we obtain an accurate marine barometer which does not require a capacity correction. By this method the extreme length of the scale is marked on the instrument, and instead of laying off true inches from the upper point downward, the inches are shortened in proportion to the relative size of the diameter of the tube and of the cistern. Barometers with scales contracted or compensated in this way are now known as "Kew barometers" (p. 19).

This method has also grown into favour for station barometers. For the ordinary kind, mounted in wood, it is especially suited, as it does away with the necessity for a capacity correction; but for standards it is not to be preferred to Fortin's plan. All marine barometers should be graduated on this principle. (See p. 20).

The fourth plan is that employed in syphon barometers (p. 23). In such instruments the mercury as it sinks in the long closed leg of the tube rises in the short open one, and *vice versâ*, and the reading of the barometer is the difference in level of the mercury in the two legs. Syphon barometers.

We have spoken of the capacity correction for barometers. There is another correction required owing to the capillary action between the glass tube and the mercury in it. This will be explained at p. 29.

Reading the Barometer.

Principle of the Vernier.—In order to facilitate the taking of accurate readings of the height of the barometer, a small moveable scale, called a "Vernier," from the name of its inventor, is attached to the instrument. Principle of the vernier.

The general principle of this moveable dividing scale is that a given length containing n divisions of the fixed scale is divided into $n+1$ or $n-1$ divisions on the vernier. In standard barometers twenty-five spaces in the vernier are equal to any twenty-four spaces of the scale, which are each half a tenth, or five hundredths, of an inch; therefore a space on the scale is larger than a space on the vernier by the twenty-fifth part of ·05 inch, which is ·002 inch, so that the vernier exhibits differences of ·002 of an inch.

Setting the Vernier.—The vernier is moved by a rack and pinion. Turn the milled-head of the pinion (see Fig. 5, p. 18.) so as to bring the *lower* edges of the vernier exactly on a level with the top of the mercurial column, which is usually convex. When set properly, the front edge of the vernier, the top of the mercury, and the back edge of the vernier should be in the line of sight, which line will thus just touch the *middle* and *uppermost* point of the column. Great care should be taken to acquire the habit of reading with the eye exactly on a level with the top of the mercury. The vernier edge must not be brought too low, or it will correspond with a chord of the curve formed by the surface of the mercury instead of being a tangent to that curve.

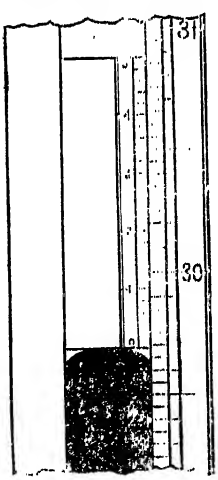


Fig. 1.

Just before setting the vernier one or two taps should be given to the barometer, by the hand, of sufficient force to cause the top of the mercurial column to be agitated. This operation overcomes the tendency of the mercury to adhere to the glass, and allows Tapping the barometer.

the force of capillarity to exert its normal action. If ever the difference of height thus caused is of any importance, it is when the pressure of the air is rapidly changing, and the barometer in kept perfectly undisturbed. A beginner should watch the effect of tapping, in order. that he may learn the necessary amount of force to use, which should never be exceeded for fear of damage to the instrument.

Setting the vernier.

A piece of white paper placed behind the tube, so as to reflect the light, assists in setting the vernier accurately. A small bull's-eye lamp or a candle held at the side of the instrument, so as to throw the light on the paper, enables the observer to get a correct reading at night. When observing the barometer, it should hang *freely*, not being inclined by holding or even by a touch; because any inclination will cause the column to rise in the tube.

The usual graduations of the scale and vernier for English barometers are as follows:—

Every long line	cut on the barometer scale corresponds to - -	a tenth	(·100)	of an inch.
" short "	" "	five hundredths	(·050)	"
Every long line	cut on the vernier scale corresponds to - -	one hundredth	(·010)	"
" short "	" "	two thousandths	(·002)	"

Reading the barometer.

Reading the Barometer.—The mode of reading off may be learned from a study of the following diagrams, in which A B represents part of the scale, and C D the vernier, the *lower* edge D denoting the position of the top of the mercurial column. The scale is readily understood; B is 29·000 inches; the first line above B is 29·050; the second line 29·100, and so on. The first thing is to note the scale line just below D, and the next is to find out the line of the vernier which is in one and the same direction with a line of the scale. In Fig. (2), the lower edge of the vernier, D, is supposed to be in exact coincidence with scale line 29·5; the barometer therefore reads 29·500 inches. Studying it attentively in this position it will be perceived that the vernier line *a* is ·002 inch below the next line of the scale. If, therefore, the vernier be moved so as to place *a* in a line with *z*, the edge D would read 29·502. In like manner it is seen that *b* is ·004 inch away from the line next above it *on the scale*; *c*, ·006 inch apart from that next above it; *d*, ·008 inch from that next above it; and 1, on the vernier, is ·010 below *y*. Hence, if 1 be moved into line with *y*, D would read 29·510. Thus the numbers 1, 2, 3, 4, 5, on the vernier, indicate hundredths, and the intermediate lines the even thousandths of an inch. Referring now to Fig. (3), the scale line next below D is 29·650. Looking carefully up the vernier, the third line above the figure 3 on it is seen to lie evenly with a line on the scale. The number 3 indicates ·030, and the third subdivision ·006; and thus we get—

Reading on scale - -	29·650
Reading on vernier -	·030 ·006
Actual reading - -	29·686 inches.

Sometimes two pairs of lines will appear to be almost coincident; in which case the intermediate thousandth of an inch should be set down as the reading. Thus, suppose the reading appears to be 29·684 or 29·686, the mean 29·685 should be adopted.

Reading the barometer.

FIG. 2.

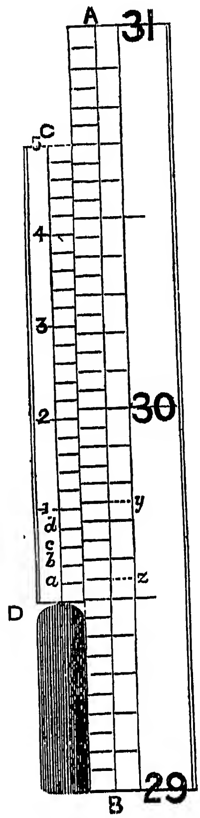
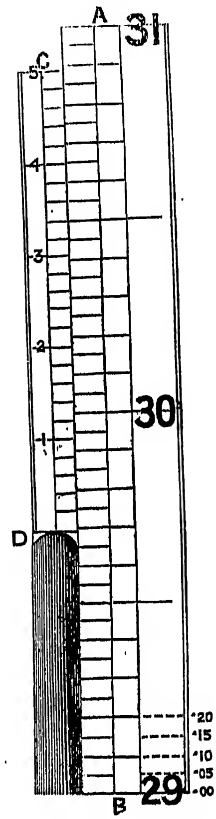


FIG. 3.



Attached Thermometer.—Every mercurial barometer should have an accurate thermometer attached to its frame, the bulb of which should be turned inwards so as to be as near as possible to the barometer tube. The thermometer may also be plunged in an open glass tube of the same section as the barometer tube, which is full of mercury and attached to the frame of the barometer. The degrees should be etched upon its stem, and, of course, a numbered scale should be placed by its side. No reading of a barometer is complete without a notation of the temperature at the same time, which should be taken before the barometer itself is read, so that this "attached thermometer" is an essential part of the barometer. The reason of this statement is explained at p. 30, and tables for "correcting" the readings for temperature will be found in App. I., p. 82.

Attached thermometer.

DEFECTS OF BAROMETERS.—AIR IN TUBE.

It has been said that the space above the mercury in the tube should contain nothing but a little of the vapour of mercury, but

Air or moisture in tube. it happens occasionally that small quantities of air creep up between the mercury and the inner surface of the tube, or that a little moisture may have been left in the tube from the process of washing it out. The slightest trace of moisture is very detrimental, as it makes the mercury adhere to the glass, and so causes the barometer to be sluggish in its action, besides affecting its accuracy by depressing the column of mercury. Should the glass become smeared by the mercury, so that the mercury appears to cling to the tube, the presence of air or moisture may be assumed, and the instrument should be sent to the maker to be reboiled, refilled, or fitted with a new tube as may be necessary. To know whether a tube with mercury has been well boiled, it is unnecessary to watch the process. It is sufficient to examine the tube with a lens. The absence of small specks and minute bubbles may be considered a satisfactory indication. It is sometimes recommended to cause the mercury to strike the top of the tube; a clear metallic "click" indicating a proper condition of the mercury, while a dull sound gives evidence of the presence of air or vapour in it; but, unless the tube be very gradually inclined, it may be broken by the momentum of the mercury in it, and there seems to be no general necessity for incurring such a risk: it should therefore never be attempted without very good reason.

Pipette. In order to prevent the access of air or moisture to the vacuum it is the practice to insert a small funnel or pipette in well made barometer tubes, somewhere between the range of the column and the cistern neck. The pipette was first suggested by Gay Lussac, in order to stop the ascent into the vacuum of air or moisture which may work its way from the cistern into the tube between the glass and the mercury, for this will lodge at the shoulder A as represented by the white space. (The figure in the margin (Fig. 4) represents the portion of a marine barometer tube which contains the pipette A B. The lower part of the tube has a contracted bore down to the cistern. The upper part, as far as the scale portion, in such barometers, is contracted even to a finer bore than that represented in the figure, to obviate "pumping," see p. 19).

A

B

Fig. 4.

"Boiling" tubes. Experience proves that instruments deteriorate less rapidly with this contrivance than without it. Cases, however, occasionally occur in which it does not effectually prevent the ingress of air and moisture, and it then becomes necessary to boil the tubes over a gas or charcoal stove to expel them. All barometer tubes should be thus treated as soon as made, in order to expel any air or moisture which may have been left behind in the process of filling, the effect of which would be to depress the column of mercury in the tube.

Removal of air bubbles from barometers. The tubes of standard and of some other barometers are not contracted like those of marine barometers, and so it is not very difficult to remove any air which may get into them. Should it be suspected that there is air in such a barometer, and there are no facilities for sending the instrument to an optician to be set to rights, it should be taken down and inclined *very* gently till the

mercury fills the tube. On inclining it still more, so as nearly to invert it, the air, if present, will ascend in a bubble into the cistern, unless it be a very minute quantity and be detained by adhesion, in which case the top may be slightly tapped on the ground to facilitate its exit. Should air have got into a marine barometer its removal is a difficult matter, and the instrument should be sent to the maker. Removal of air, &c. from barometers.

Sometimes, though very rarely, a particle of dirt or a bubble of air lodges in the very fine contraction of the tube of a marine barometer, and completely stops the action of the instrument. Whenever, therefore, a marine barometer becomes stationary or inactive when it evidently ought to be moving under the influence of atmospheric changes, there being no evidence of fracture of the glass, the cause may be surmised to be of this nature. It should then be taken down, the mercury allowed to fill the tube, and the instrument put aside, in an *inverted* position, for a few hours. On replacing it, the cause of the stoppage will generally be found to have been removed to a part of the tube where it can do no harm.

MANAGEMENT OF BAROMETERS.

In handling barometers it should always be remembered that they are delicate and expensive instruments. The result of rough treatment is breakage; and for scientific purposes, observations from an instrument improperly repaired and not verified are useless.

Packing and Transmission.—Experience shows that it is advisable to give some directions as to packing barometers. The instrument having been taken down and placed in its box, as directed under the head of each special type of instrument, should, if it is to be sent by rail or other conveyance, and is likely to be handled by persons unacquainted with its delicate and peculiar construction, be placed in a packing case with two or three inches of soft elastic packing all round it, as hay, straw, shavings, tow, or paper-cuttings. The lid of the case should *never be nailed down*, but always fastened with screws. The address label should be *pasted* (not nailed) on the end of the case which is next the cistern, or lower end of the barometer, and it should be marked "Glass and fragile instruments. Keep this box lying flat, or carry it this end upwards." Of course, if two or more barometers are packed together, the cisterns should all be placed at this marked end of the case. Barometers should be transmitted by passenger train, and, in short, always by whatever route or conveyance affords the safest transit. Transhipment or change of conveyance should be avoided, if possible. Packing for transmission.

Position.—The barometer may be placed in any convenient room, but should be fixed in a good light for observing, out of the reach of sunshine and as much as possible out of the direct heat from a fire or lamp, and should not be exposed to sudden changes of temperature. Great pains must be taken to ensure Suspension.

that the instrument hangs absolutely vertically, for the slightest divergence from a perpendicular position will cause an appreciable error in the readings, making them always too high. It should also hang where it can be carefully protected from injury.

Different Kinds of Barometers in use.

A short description of the principal kinds of barometers will now be given, omitting all mention of constructions which have not proved generally useful, such as long-range barometers, and those with distorted scales, or with spiral and diagonal tubes.

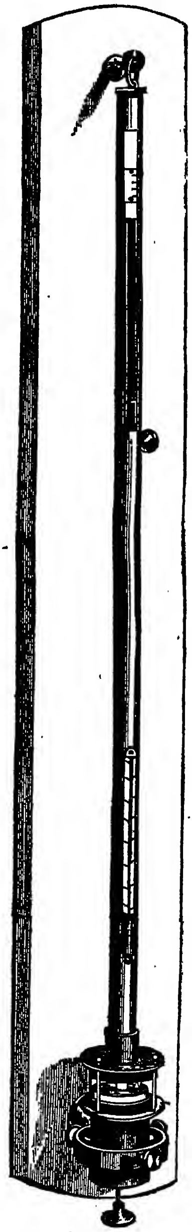


Fig. 5.

Barometers on Fortin's principle. Standard Barometer.

Land Standard Barometer.

The best standard barometers are made on Fortin's principle, which was mentioned on p. 12. In these instruments the upper part of the cistern is made of glass, the base is pliable, and acted upon by a lifting screw. The zero of the scale is visible in the cistern, being generally a piece of ivory, whose lower extremity is called the *fiducial point.* The level of the mercury in the cistern must be set to this point, before taking the reading, by raising or lowering the cistern base by means of the thumb screw. The tube is mounted in a brass case, which is suspended from a hook at the top of a mahogany board, so as to ensure perpendicularity (Fig. 5). At the lower end of the board is a socket or ring, with clamping screws, for steadying the instrument in a vertical position when an observation is to be made. The instrument is so suspended that it may be turned at pleasure to any source of light for setting and reading the vernier. A sheet of white notepaper fixed on the board, just behind the top of the mercury, will also be found serviceable in reflecting the light so as to enable a good observation to be made. The vernier is constructed to read to $\frac{1}{500}$ of an inch, or by estimation to ·001 inch, and is adjusted by a rack and pinion motion.

Barometers on Fortin's principle can only get out of order by the ingress of air or moisture. They are not affected by any changes which may take place in the material of the cistern or the mercury therein. The scales are engraved by a dividing engine, and are usually laid down with accuracy. The only scale error likely to exist arises from incorrect fixing of the zero point; it will, however, be constant throughout the scale, and can suffer no change from use of

the instrument; moreover the position of the mercurial surface is independent of loss of mercury from oxidation, &c. The mode of testing a standard barometer will be found at p. 27.

Management of standard barometers.

When sent into the country or abroad, a standard barometer is usually packed, apart from the mahogany board, in some soft elastic material, the screw at the bottom being turned so as to fill the tube and cistern with mercury. It should not be handled until a position has been selected for it, and then it must be very carefully unpacked. It should be suspended so that the scale may be about five feet from the ground or floor, and that the zero point in the cistern and the vernier on the scale may be easily seen. The board should first be fixed against the wall, the cistern then inserted into the socket, the instrument suspended from the hook, and its perpendicularity secured. When this is done, the thumb screw at the bottom should be reversed till the mercury in the cistern falls to the level of the ivory point.

Reading a standard barometer.

To set the Barometer, first read the attached thermometer, then adjust the mercury in the cistern by means of the thumb-screw, (the tube being held vertical by the clamping-screws,) so that it exactly touches the ivory point, which, with its reflection (if the surface of the mercury be clear,) will then appear as a double cone. Next adjust the lower edge of the vernier tangentially to the convex surface of the mercury in the tube, by keeping the eye in line with the back and front edges of the vernier, see p. 13. It requires a little practice for the novice to make these adjustments properly and expeditiously. While it is all-important that they should be done properly, it is advisable to do them quickly in order to avoid raising the temperature of the instrument by the proximity of the observer's person.

The method of correcting and reducing the readings will be found at p. 32.

Marine Barometers.

Marine barometers.

It is necessary that a portion of the tube of a barometer intended for use at sea should be made with a very fine bore, as will be seen in fig. 4, p. 16, in order to check the oscillations of the mercurial column which would otherwise occur from the motion of the ship. When the bore is not *sufficiently* contracted, the ship's motion causes fluctuations in the mercury in the tube, to which the term "pumping" is applied. Of course this "pumping" is objectionable, as at times correct readings cannot be obtained. On the other hand, when the contraction is too fine, the instrument is sluggish in responding to the varying pressure of the atmosphere, and is proportionally ill-adapted for accurate observations.

Kew barometers.

Kew Marine Barometer.—In 1854, the Kew Committee of the British Association were requested by Government to recommend a form of barometer suited for the marine observations, which were then about to be commenced by the Admiralty and the Board of Trade, in accordance with the resolutions adopted at

Kew barometers.

the Brussels Conference. Accordingly, by direction of the Committee, Mr. John Welsh, at that time in charge of Kew Observatory, made special experiments to ascertain the appropriate limits of contraction for marine barometer tubes. The reply of the Committee to the Board of Trade stated that "in selecting the form "of marine barometer best adapted to the purpose of making "observations at sea, the Committee have endeavoured to combine "convenience and economy with accuracy, durability, and simplicity "in construction and adjustment.

"The barometer proposed by Mr. Adie appears to them to "fulfil those conditions in a satisfactory manner." *

Construction.

Accordingly this barometer has been adopted by the Government. It is in all respects a trustworthy instrument, and is equally available for land or sea service. It is not too sluggish for accuracy on land, while at sea the motion of the ship is rather favourable than otherwise to its correctness of action. It is mounted in a brass case, but, as this alloy is liable to be acted upon by mercury, the cistern is made of iron. The case is open in front and rear so as to expose to view the range portion of the tube, and the scale is protected from dust by a glass shield (see Fig. 6, p. 21). The vernier is engraved on a small piece of silvered brass tubing, and travels firmly, by a rack and pinion motion, the parts being kept in position by friction. The vernier is similar to that in a Fortin's standard barometer, and enables the height of the mercurial column to be read by estimation to the nearest thousandth of an inch. See p. 14.

The inches of the scale are contracted to compensate for the alterations in the level of the mercury in the cistern, as has already been explained.

In the Government marine barometers the diameter of the cistern is about 1·25 in., and that of the tube about 0·25 in. The scale, therefore, instead of being divided into inches in the usual way, is shortened in the proportion of 0·04 of an inch for every inch.

The cistern.

The cisterns of all marine barometers are closed. Each contains sufficient mercury to cover the open end of the tube in whatever position the instrument may be placed; so that no adjustment of cistern whatever has to be made, either for portability or for observation. The observer should never attempt to meddle with the cistern. Cisterns made of wood are sufficiently pervious to air for the mercury to be affected by the variations of the pressure of the atmosphere. Those made of iron are provided with a small aperture at the top or cover, which is closed internally by a piece of leather, through which the air can act, but the mercury cannot escape.

Every tube is constructed with an air-trap, similar to that already described, p. 16.

"Gun" barometer.

"Gun" Barometer.—A modification of the marine barometer, for the Naval Service, intended to withstand the concussion arising from gun-firing, was designed in 1861 by Admiral FitzRoy,

* The precise regulations as to the tests for sufficiency of contraction, &c. which are at present in force will be found at p. 29, when treating of the testing of marine barometers.

its use being rendered necessary by the greatly increased size of modern artillery. In this instrument the glass tube is surrounded as much as possible with vulcanized india-rubber tubing, as packing, which checks the vibration arising from concussion, but does not hold the tube rigidly. The cistern is made entirely of seasoned box-wood, but would be improved by the substitution of iron, as being more durable, and preserving the mercury better from oxidation and moisture. Formerly these barometers were only graduated to 0·01 in., but they have lately been fitted with improved verniers and accurate scales, so as to read as closely as the Kew marine barometer, from which they therefore now differ only in details. "Gun" barometer.

Directions for Handling.—Barometers when in use at sea are slung in gimbals, and suspended from arms at least a foot long (Fig. 6), so as to be perfectly free to assume the vertical position under every movement of the ship, and at the same time to keep clear of the bulkhead against which the arm is fastened. It is desirable to place them in such a position as not to be in danger of a side blow, and also sufficiently far from the deck above to allow for the spring of the mètal arm in cases of sudden movements of the ship. If there be risk of the instrument striking anywhere when the vessel is pitching or rolling heavily, it will be well to put some soft padding on that place. It is essentially necessary that the instrument should have free swing. No steadying springs or stays of any kind should be applied to a barometer, as by their weight they at all times keep it slightly out of the vertical, and when they come under stress the instrument is in an abnormal position altogether. *Care should be taken that no readings from a barometer which is not hanging truly vertically should ever be recorded.* Such readings will always be too high in proportion to the degree of obliquity. Suspension of marine barometers.

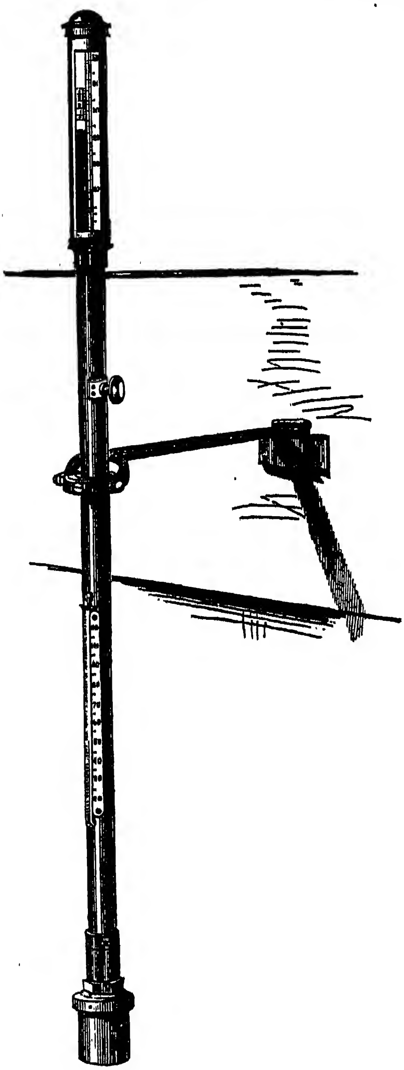


Fig. 6.

Various contrivances have been resorted to for rendering the arm and gimbals elastic, so as to yield to sudden jerks. Experience proves that a simple straight arm of well-hammered brass has sufficient spring for the purpose.

When these barometers are used at land stations the arm is made much shorter, but in all other respects the instrument is mounted as shown in the figure.

Fixing up.

A bracket and screws for suspending the barometer are in its box. Screw up the bracket where the barometer is to be hung. Then lift the instrument carefully out of its box, bend back the hinged part of the suspension arm, and slip it into the bracket. (The holding screws should not be driven quite home until the instrument is in position.) The mercury will then fall gradually, and the instrument will usually be ready for observation in about an hour. In a well boiled tube the mercury sometimes remains immoveable, and will not quit the top of the tube. If after the lapse of a few minutes the mercury has not left the top of the tube, tap the cistern end rather sharply with the fingers, or make the instrument swing a little in its gimbals. This difficulty very rarely happens, and no precise mode of treatment can be laid down: the remedy lies much at the judgment of the observer, who should use such means, but never violent ones, as he may deem best to cause the mercury to fall. The box should be safely stowed away.

Taking down.

Whenever it may be necessary to take down a barometer and stow it in its box, *the vernier should be brought down to the bottom of the scale.* Then, having lifted the instrument out of the bracket, place or hold it in an *inclined* position for a few minutes so as to allow the mercury to flow *very gently* up to the top of the glass tube. It should then be taken lengthwise and laid in its box, when it is portable, without any other adjustment whatever, and may be carried with the *cistern end upwards* or *lying flat*, but it must not be subjected to jars or concussions.

To set the Barometer.—As there is no adjustment of the cistern requisite, or in fact possible, in these barometers, all that is necessary is to read the attached thermometer, and then to adjust the vernier and read off as directed at p. 14.

Common marine barometers.

Common Marine Barometers are not made on any uniform system, either as regards the contraction of the tubes, the compensation of the scales for capacity, or the introduction of the air-trap to prevent deterioration. They are cased in wood, and are showy instruments. Their usual faults are either sluggishness from over contraction, or pumping from insufficient contraction. The scale-errors are sometimes of considerable magnitude, and differ in value at different parts of the scale; while the mercury itself is frequently impure, owing to oxidation or to the presence of moisture.

The cistern is made of box-wood with a pliable leather base, to which a lifting screw is attached. This arrangement is solely intended to render the instrument portable. It is covered by an outer brass casing. After fixing up such an instrument the brass casing should be unscrewed, and the flexible base of the

cistern let down. Before changing the position of the instrument, or taking it down for carriage, the cistern should be screwed up so as to confine the mercury in a close space.

As regards the use of such instruments it need only be repeated that even if their construction were otherwise accurate, no readings from barometers mounted in wood can be said to possess any scientific value whatever in comparison with those from instruments mounted in metal.

Syphon Barometers.

The tube of a barometer may be bent up at the open end in the shape of a syphon, with the short limb from six to eight inches long. This does away with the necessity for a cistern; for, when sufficient mercury is introduced into such a tube, the atmosphere supports the mercury in the long limb, which is closed at the top, by its pressure upon that in the short limb. As the barometrical column rises and falls, the mercury in the short limb falls and rises; therefore, provided the calibre of the upper part of the long limb be equal to that of the short limb (so that the effect of capillarity is the same in each), the distance between the upper and lower levels of the mercury is always the height of the barometric column. A scale of inches starting from a zero point taken near the bend of the tube, with verniers fitted to each limb, gives the means of measuring the long and short columns. The difference of readings is the height of the barometer. By another method the zero point is taken at some intermediate position, and the distances of the mercury levels being measured therefrom, upward and downward, their sum is the height of the barometer. Syphon barometers.

As the capillary action of the glass is considered to be the same at each of the mercury surfaces, no correction for capillarity, p. 29, is required. If, therefore, a correct scale of inches be applied, the instrument should have no error; but practically this is hardly ever the case. The index error should be determined by comparison with an acknowledged standard barometer. The correction for temperature is applied, as for other barometers, according to the material on which the scale is mounted.

As a standard station barometer the syphon tube is but little used in this country, though it is very generally adopted on the Continent, and in fact the Permanent Committee of the Vienna Congress have recorded their opinion as follows:—

"That if we speak of the comparison of standard barometers at central
"stations, and wish to attain an accuracy of 0·03 mm., (0·0012 in.), the usual
"travelling barometers would not be sufficient, but that syphon barometers of
"a diameter of at least 12 mm., (0·47 in.), were requisite, in which, moreover,
"the mercury should always be caused to rise in both legs, immediately before
"the reading."

Mountain Barometers.

The syphon form of tube has been much used for mountain barometers; as, from the absence of a cistern, and the small quantity Mountain barometers.

Mountain barometers.

of mercury required, it makes a light and compact instrument. Instead of the top of the short limb being left entirely open, it is closed, and a small conical puncture is made at the side, which is bound round with cotton wool, so that the instrument may be inverted for travelling without any mercury escaping. The portion in the short limb is then loose in its part of the tube, but, as there is little of it, there is no danger of its breaking the tube by its momentum if ordinary care be taken in moving the instrument. The tube is contracted along the intermediate portion and round the bend, so that the mercury, filling it when inverted, is retained there while travelling.

Ordinary Barometers.

Before leaving the subject of barometers, it is well to say a few words about the commonest forms of barometers in use on land, although, as already explained, such instruments cannot lay any claim to be considered as scientific instruments at all.

Common land barometers.

The common land barometer is generally mounted in wood. The cistern may have a flexible base, but if so, its purpose is merely for screwing up the mercury so as to fill the tube and render the instrument better adapted for carriage from place to place. As a rule these barometers are useless for scientific records (see p. 28). Like the wheel barometers, they are household instruments, used as weather glasses, which name they have received from the practice among the makers of engraving the following formulary on their scales:—

At 31 inches	Very dry.
30·5 ,,	Settled fair.
30 ,,	Fair.
29·5 ,,	Changeable.
29 ,,	Rain.
28·5 ,,	Much rain.
28 ,,	Stormy.

These words are very objectionable, since they do not satisfy different conditions of elevation above the sea, or of geographical position, and are also totally wrong from a meteorological point of view. They were, no doubt, intended to refer to the action of the barometer when placed at or near the sea level; but even with that limitation they are not correct, for weather depends on many other circumstances than mere atmospheric pressure.

Coast or "Fishery" Barometer.

"Fishery" barometers.

This form of barometer (Fig. 7, p. 25) was designed by Admiral FitzRoy, who also devised the lettering to be seen in the figure, which has to a great extent superseded that of old date, mentioned above. It was intended to be simple, durable, and sufficiently accurate for all practical purposes as a weather glass. The case is made of oak, and fastened by brass screws. There are no glued pieces nor iron fastenings which might be acted upon by mois-

ture. The tube shows a broad column of mercury. It dips in a well seasoned box-wood cistern, which has a flexible base made of sheepskin, and is provided with a lifting screw. The scale plates are porcelain, and have the lettering burnt in. The vernier reads to hundredth parts of an inch, and one is fixed on each side of the tube to facilitate the observation of changes of pressure. The attached thermometer is large and easily read. It will give the temperature of the air, as well as that of the barometer, when the instrument is freely exposed, provided it is not exposed to sunshine. "Fishery" barometers.

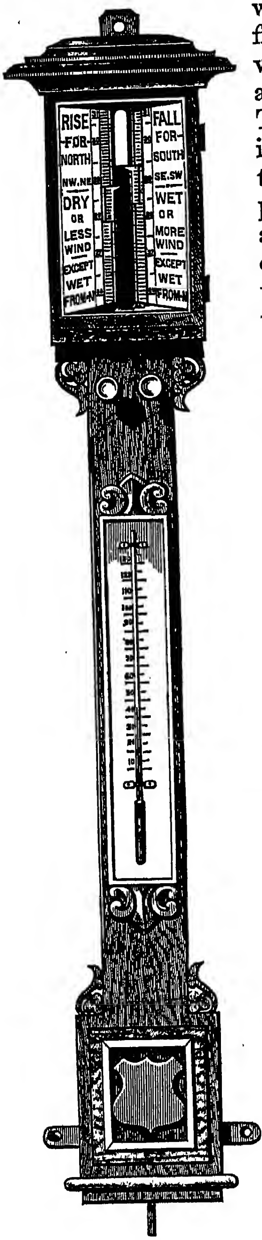


Fig. 7.

The Meteorological Office has placed about 120 barometers of this description at exposed positions on the coasts of the British Isles for the use of fishermen, seafaring persons, and the public generally. The instrument is admirably suited for erection as a public weather glass.

Directions for Handling.—This barometer should be suspended on a hook or stout nail, against a frame or piece of wood, in the shade, so that light may be seen through the tube. Otherwise a piece of white paper should be placed behind the upper or scale part of the tube. When first suspended, take the pinion key (from the lower end of the scale), fit it on the square-headed brass pin at the lower extremity of the instrument, and turn gently to the left, or against the sun, till the screw stops; then take off the key, and replace it for use on the vernier pinion near the scale, where it should remain, to be used in moving the vernier. The cistern base being thus let down, the mercury in the tube comes at once to its proper level. Management.

In removing this barometer it is necessary to slope it *very* gradually, till the mercury is at the top of the tube, and then, with the instrument reversed, to screw up the cistern base or bag, by the pinion key, used gently, and turned to the right till it stops. It will then be portable, but should be carried with the cistern end uppermost, or lying flat, and it must not be jarred or receive a concussion.

Wheel Barometer.

The syphon tube is greatly used for the construction of the household weather glass known as the Wheel Barometer. In this Wheel barometer.

Wheel barometer.

instrument the mercury in the short limb carries a float, to which a silk cord is attached, and carried over, and two or three times round, a fixed pulley, the other end being counterpoised and kept in a guide tube to prevent its oscillating. The axis of the pulley carries a pointer in front of a dial mounted on the wooden case of the instrument. As the barometer rises the float descends, and the cord drags the pointer to the right; as it falls the float rises and the counterpoise brings back the pointer to the left. The dial is graduated to correspond with the inches and divisions on an ordinary barometer, usually from 28 to 31 inches. The arrangement gives a very open scale; for, although the actual movements of the mercury are only half of what they are in an ordinary barometer, yet the pointer, traversing a large arc, multiplies their linear extent. It will be apparent that as the mercury rises, say half an inch, in the long tube, the fall in the short limb being also half an inch, the length of the barometrical column, which is the difference between the heights of the two surfaces, has increased one inch; but for this increase of one inch there has only been movement through half an inch, and this is the amount of movement given to the pulley, and is shown on the dial as a change, say from 29 to 30 inches.

The inertia arising from the weight of the float and the friction of the cord and pulley render the instrument at all times sluggish, but more especially so at the times of change from a falling to a rising barometer, and the converse. The most perfect barometer must always be a little behind the actual changes of atmospherical pressure, considered as pressure merely, because of the inertia to be overcome arising from the weight of the mercury and its friction against the glass tube. The mercury of a barometer is, moreover, virtually a body in motion, and must obey the law of inertia, which teaches that the motion will continue after the cause has ceased to produce it, until its energy is destroyed. Whenever, therefore, we seek to make the barometrical column perform work as in the wheel barometer, or in the registering barometers which act mechanically, we increase the inertia, and consequently render the instruments more sluggish than they otherwise would be. This circumstance has induced meteorologists to resort to the photographic method of recording the height of the barometer, examples of which are the barographs used at the observatories of the Meteorological Committee. For a description of this instrument, see the Report of the Meteorological Committee for 1867.

Substitutes for Mercurial Barometers.

Aneroids and metallic barometers are useful substitutes for the mercurial barometer as weather-glasses.

The aneroid.

The Aneroid is an instrument which has come into extensive use, owing to its convenient size and portability. These recommendations have at once secured its very general adoption.

In the aneroid, atmospherical pressure is measured by its effect in altering the shape of a small, hermetically sealed, metallic box,

from which almost all the air has been withdrawn, and which is kept from collapsing by a spring. The top of the box is corrugated. Aneroids.

When the atmospherical pressure rises above the amount which was recorded when the instrument was made, the top is forced inwards, and *vice versâ*, when pressure falls below that amount, the top is pulled outwards by the spring. These motions are transferred by a system of levers and springs to a hand which moves on a dial like that of a wheel barometer.

It is at once evident that the instrument must be graduated experimentally, as it cannot measure pressure absolutely, but affords indications relatively to a mercurial barometer (its sensibility depending *inter alia* on the quality of the metal of which the box is made).

The principle of the metallic (Bourdon's) barometer is somewhat similar to that of the aneroid.

Aneroids are very sensitive, but unfortunately they do not preserve their accuracy. If a table of corrections be determined for an aneroid, it will be found that after a time it has undergone some change, and that the values of the corrections will require alteration, so that re-comparison with a standard barometer will be necessary. In every case of such comparison the readings of the mercurial barometer should be reduced to 32°.

A most serious objection to the scientific utility of these instruments is their liability to injury, owing to rust or to the alteration of force in the springs used in their construction. However, for the reasons above stated, the aneroid is especially suitable for fishermen, pilots, or seafaring persons employed in boats or small coasting vessels, in which there is not space to suspend a barometer; and, of course, all that is stated regarding the barometer as a weather indicator, applies to the aneroid so far as a single observer is concerned. *For concerted observations accurate mercurial barometers are indispensable.*

Verification of Barometers.

Before barometrical observations can be of any real use for scientific purposes, there must be satisfactory evidence that the errors of the instruments used have been properly ascertained and applied.

A Fortin's barometer should be carefully compared with a recognised standard. The difference will be the constant correction which is to be applied to its reading, and will include the error of graduation combined with the error arising from the capillary action of the glass tube upon the mercury, see p. 29. In some certificates, however, these two corrections are given separately. The inches laid down upon the scale should also be tested by a standard scale. This is the plan followed at the Kew Observatory. Standard barometers.

It is a work of much more time to test the "Kew" barometer, since it is necessary to find the correction for scale readings at each half inch throughout the range of atmospheric pressure to which "Kew" barometers.

Testing "Kew" barometers.

it may be exposed; owing to the fact that the inches marked are not true inches; and it becomes necessary to have recourse to artificial means for changing the pressure of the atmosphere on the surface of the mercury in the cistern.

At the Kew Observatory the barometers to be thus tested are placed, together with a standard, in an air-tight chamber, connected with an air pump, so that, by partially exhausting the air, they can be made to read much lower than the lowest pressure to which marine barometers are likely to be exposed; and by compressing the air they can be made to read higher than the mercury ever stands at the level of the sea. The tube of the standard with which they are comparêd is contracted similarly to that of the marine barometer, but a provision is made for adjusting the mercury in its cistern to the zero point. Glass windows are inserted in the upper part of the iron air-chamber, through which the scales of the barometers may be seen; but as the verniers cannot be moved in the usual way from outside the chamber, a provision is made for reading the height of the mercury, independently of the verniers attached to the scales of the respective barometers, by an instrument called a Cathetometer. At a distance of some five or six feet from the air-tight chamber a vertical scale is fixed. The divisions on the scale correspond exactly with those on the tube of the standard barometer. A vernier and telescope are made to slide on the scale by means of a rack and pinion. The telescope has two horizontal wires, one fixed, and the other capable of being moved by a micrometer screw, so that the difference between the height of the column of mercury and the nearest division on the scale of the standard, and also of all the other barometers placed by the side of it for comparison, can be measured either with the vertical scale and vernier or with the micrometer wire. The means are thus possessed of testing barometers for index error in any part of the scale, through the whole range of atmospherical pressure to which they are likely to be exposed, and the usual practice is to test them at every half inch from 27·5 to 31 inches. The errors detected include not only the index error but the correction for capillarity, p. 29.

Defects of ordinary barometers.

In this way *ordinary* barometers of various constructions have been tested, and some found to read half an inch, or more, too high, while others read as much too low. In some cases those which were correct in one part of the scale were found to be several tenths of an inch wrong in other parts. In some the mercury would not descend lower than to about 29 inches, owing to a fault till very lately usual in the construction of common barometers,—*the cistern was not large enough* to hold the mercury which descended from the tube at the time of a *low atmospherical pressure.*

Conditions for Barometers enforced at Kew, 1875, for instruments required for the Meteorological Office.

For *Barometers professing to be Standards.*—All of which the index error at the ordinary pressure is greater than 0·010 inch are rejected.

For Marine Barometers.—All are rejected of which the index error at the ordinary pressure is greater than 0·015 inch, or the capacity error greater than 0·004 inch, or for which the mercury takes less than 3, or more than 6, minutes to fall from the height of 1·5 inches to that of 0·5 inch above the present pressure. Conditions for marine barometers.

This latter condition is to ensure the efficiency of the contraction as a provision against "pumping" (p. 19), as well as to prevent the danger of the barometer being too sluggish from over contraction.

Correction of Barometrical Observations.

We have already mentioned the fact that corrections must be applied to all barometer readings, in order to bring the indications of different instruments into harmony with each other, before they can be used for scientific purposes. Some of these corrections have reference to the special instrument, while others are applied to the reading of any instrument taken under the same conditions.

The corrections of the former class are three in number :—

I. Index error.
II. Capacity.
III. Capillarity.

Those of the latter class are two :—

IV. Temperature.
V. Altitude above the sea level.

I. Correction for Index Error.—This is applied according to the errors discovered in the individual instrument when verified as explained at p. 27. It may be either additive (+) or subtractive (−).

II. Correction for Capacity.—In barometers possessing closed cisterns with a scale of true inches engraved on the case, there is a certain height of the column which is correctly measured by the scale. When the mercury sinks below this position, called the *neutral point,* the level rises in the cistern above the zero of the scale, and then the height read off must always be too great. When the mercury rises above the neutral point the level in the cistern sinks below the zero point, and the reading is too small. On the scale of such a barometer the maker should mark the neutral point, and state the ratio of the interior area of the tube to that of the cistern thus: Capacity $\frac{1}{50}$. From these data, the corection for capacity is found by taking a 50th part of the difference between the height read off and that of the neutral point, adding it to the reading when the column is higher, and subtracting it from the reading when it is lower, than the neutral height.

It will be remembered that Fortin's and syphon barometers require no correction for capacity.

III. Correction for Capillarity. — The indications of barometers are affected by the capillary action between the glass tube and the mercury, the effect of which is constantly to depress

Capillarity correction.

the mercury by a certain quantity nearly inversely proportional to the diameter of the tube.

The correction, therefore, is always additive.

This depression is greater in tubes in which the mercury has not been boiled (p. 16) than in those which have been subjected to this process.

The following table from the Report of the Committee of the Royal Society on Physics and Meteorology, 1840, gives the corrections to be applied to English barometers. It takes into account the diameter of the tube, but not the variations of the height of the *meniscus*, i.e. the convexity which terminates the column :—

Diameter of Tube.	Correction for	
	Unboiled Tubes.	Boiled Tubes.
Inch.	Inch.	Inch.
0·60	0·004	0·002
0·50	0·007	0·003
0·45	0·010	0·005
0·40	0·014	0·007
0·35	0·020	0·010
0·30	0·028	0·014
0·25	0·040	0·020
0·20	0·060	0·029
0·15	0·088	0·044
0·10	0·142	0·070

The certificates furnished from Kew Observatory for all barometers verified there, give the results of direct readings of the column at different heights, and so include the three corrections above mentioned, in so far as any of them are applicable to the special barometer under consideration.

Temperature correction.

Correction for Temperature, or *reduction to* 32° F.—All bodies are affected in their dimensions by heat; with few exceptions they expand when their temperature rises and contract when it falls, and it is therefore necessary, in taking any accurate measure of the length of any object, to know at what temperature the measure was made, in order that we may know what the length would have been at some definite temperature, which is taken as the standard temperature. In the case of barometers this standard temperature is 32°, and accordingly, speaking in general terms, when the barometer is at a temperature below 32° the correction is additive (+), and when it is above 32° it is subtractive (−).

Table I., p. 82, gives the corrections for barometers with brass scales, and it will be seen from it that the sign of the correction changes from + to − at the temperature of 29°, as the formula given at p. 80 gives negative results for three degrees below 32°.

The temperature of the barometer is given by the attached thermometer (p. 15), of which the bulb is so placed as to

give as accurately as possible the true temperature of the actual column of mercury. **Temperature correction.**

The pressure is given in the table for each half inch from 24 to 31 inches, as of course the correction depends on the length of the column of which the temperature is given by the attached thermometer.

In consequence of the great risk of the heat of the observer's person affecting the thermometer attached to the instrument during the process of taking a reading of the barometer, the attached thermometer is always to be read first of all, before the reading of the barometrical column is made.

Correction for Altitude, or *reduction to Sea Level.*—As the barometer measures the pressure of the atmosphere, it is evident that if that pressure be increased or diminished, the length of the barometrical column will become greater or less. If we suppose the air to be homogeneous and to rest on the surface of the earth as an outer shell of uniform thickness, it is evident that if we ascended a mountain there would be a less thickness of this shell of air above us, and therefore a less pressure, and *vice versâ* if we went down a mine there would be a greater pressure. **Altitude correction.**

Accordingly, as we have seen that the barometrical readings must be reduced to a standard temperature, to make them intercomparable, they must also be reduced to a standard level, and that is the mean level of the sea. For the British Isles the mean sea level at Liverpool has been selected by the Ordnance Survey as their datum. It is always best to determine the altitude of a station by reference to the nearest Ordnance Bench Mark.

The problem of correction for altitude is, however, not so easy as would appear from what has just been said. For simplicity we shall deal only with heights *above* sea level, as by far the most important to us:—The difference in pressure for which the correction has to be applied is for the heights of the vertical column of air which would extend from the level of the station to that of the sea. But the weight of this column differs according to its tem perature, being greater if the air is cold than if it is warm. We must therefore take into account the temperature of the air at the time, and Table II., p. 84, gives the corrections for every ten degrees, from -20° to 100°, which are about the limits within which barometrical observations are usually made. This temperature must be taken from the dry bulb thermometer, not from that attached to the barometer.

We see also from the explanation of the table given at p. 80, that as the formula enables us to find the proportion which the pressure of the atmosphere at the upper station bears to that at the sea level, the correction will vary according to the amount of that pressure at the sea level, so that two tables are given for the extreme limits of pressure which are likely to occur at the sea level, viz., 30 and 27 inches, and the corrections for intermediate readings must be obtained by interpolation.

Specimens of the mode of correcting and reducing barometer readings are here subjoined.

Correction of readings.

Firstly, if the barometer has a Kew correction, as this includes the corrections for index error, capacity, and capillarity, we proceed as follows :—

Suppose that—

Barometer reading -	= 29·946 ins.
Attached thermometer	68°
Kew correction for instrument -	= + ·014 in.
Temperature of air by dry bulb - -	= 50°
Altitude of cistern above the mean sea level - - -	= 105 ft.

Then we have—

Uncorrected reading -	= 29·946 ins.
Add for Kew correction	+ ·014
Reading - - -	29·960
Deduct temp. correction for 68° and 30 ins. - -	− ·106
Reading at 32° F. -	= 29·854
Add for altitude of 105 ft. at temp. of air 50° and *approximate* pressure at sea level 30 ins. -	+ ·116
Reading corrected and reduced to 32° F. at Mean Sea Level -	= 29·970 ins.

Secondly, if the barometer requires all the five corrections above enumerated.

We have then the following data :—

Correction for index error of instrument = + · 005 in.
Capacity correction $= \frac{1}{50}$, neutral point being 29 ins.
Capillarity correction = + · 002 in.
Altitude of cistern above sea level = 200 ft.

Let the reading of the barometer be 29·812, and of the attached thermometer 63°, while the temperature of the outside air is 60°.

Then we have :—

Barometer as read off - -	29·812 ins.
Add for capillarity - - -	+ ·002
,, ,, capacity ·812 × $\frac{1}{50}$ - -	+ ·016
" index error - -	+ ·005
	29·835
Subtract for temperature of attached thermometer, 63° barometer being 29·8 ins. -	− ·092
Reading at 32° F. - -	29·743
Add correction for altitude of 200 feet (temperature of air being 60°, and *approximate* pressure at sea level 30 ins.) - -	+ ·215
Reduced and corrected reading	= 29·958 ins.

Barometric Measurement of Heights.—It is scarcely necessary to say that the same principles as enable us to ascertain the barometrical reading at one level from that at another, when the relative heights of the two stations are known, will enable us conversely, to determine the difference of height between two stations if we know the barometrical readings and the temperature taken at each. *In other words, we can determine the height of a mountain by barometrical readings* taken on the summit and at the sea level.

Measurement of heights.

These readings ought to be taken at the same time, because it is not likely that the pressure and temperature of the air will remain unaltered while the ascent is being carried out.

There is a very important matter to be taken into consideration in respect of these calculations. The barometer is not at the same height at the sea level all over the earth's surface at any time, and even over the limited area of the British Islands the mean barometrical reading varies considerably, from 29·811 ins. at Nairn to 29·982 ins. at Plymouth (Quarterly Weather Report, 1870, App. II. p. [10]), while on individual days the differences of pressure may be far greater, amounting to an inch or more. Accordingly, as for stations in the interior of a country it is impossible to take a reading at the sea level in the immediate neighbourhood of the station whose level we have to determine, and we have to employ the means of a series of readings at the two stations, in order to avoid the risk of error from sudden changes of weather affecting the barometrical readings, we must not expect that the ascertained heights of the same mountains referred to different sea-coast stations will agree exactly with each other.

Hence we see that in the case of the barometrical measurements of elevations in the interior of continents, or of the heights of really high mountains, there are several elements of greater or less uncertainty, and accordingly such determinations cannot be so trustworthy as those for moderate elevations and for slight distances from the sea coast, which are all that is required for the purposes of barometrical readings in these islands.

THE THERMOMETER.

General Description of the Instrument.

The thermometer consists of a long glass tube, of very small bore, closed at one end and blown out at the other into a bulb or reservoir, which is filled with mercury or some other liquid. The temperature to which the instrument is exposed from time to time is indicated by the expansion of this liquid, and is measured by the length of the thread of liquid which extends from the bulb into the tube.

There are two points on the scale of a thermometer fixed by reference to natural phenomena, that at which water boils, and that at which ice begins to melt. These are called respectively the boiling and the freezing point. The scale is divided into *degrees.*

Thermometer scales.

In the thermometer which is used in England and its colonies and in the United States, namely, that designed by Fahrenheit, the distance between these points on the scale is divided into 180 degrees. The point at which ice melts is 32 degrees, and that at which water boils, when the barometer is at 29·905 inches,* is 212 degrees.

In the Centigrade thermometer (designed by Celsius), the distance between the same fixed points is divided into 100 degrees. The point at which ice melts is 0°, and that at which water boils, when the barometer is at 760 millimetres, is 100 degrees.

In Reaumur's scale, formerly much used, especially in Germany and Russia, the distance between the same points is divided into 80 degrees. Here too the freezing point is 0°; but the boiling point is 80°.

In both the two latter scales all temperatures below the freezing point have a "minus" sign prefixed to them. Thus — 10° C. or R. indicates 10° below the freezing point on either the Centigrade or Reaumur scale.

In the case of the Fahrenheit scale the zero is 32 degrees below the freezing point, so that the "minus" sign is seldom used for temperatures occurring in the United Kingdom. The Fahrenheit and Celsius scales agree at $-40°$.

Of these scales, Reaumur's, which was formerly very common, is now rapidly falling out of use, owing to the very general adoption of the Centigrade system.

Inasmuch, however, as all three scales are in existence and occasionally met with, it is well to know the following rules for converting readings according to one into readings according to either of the others.

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* The reason for saying "when the barometer is at 29·905 inches," is that the pressure of the atmosphere exerts a great influence on the boiling point of a liquid; thus, for water, a difference of pressure of one inch above or below 30 inches would raise or lower the boiling point almost exactly 1°·7 F., *e.g.* if the barometer is at 29 inches, the boiling point is about 210°·3.

To convert Fahrenheit readings to Centigrade. Thermometer scales.

Subtract 32 and multiply the remainder by $\frac{5}{9}$

$$e.g.\ 68°\text{F.} = (68-32) \times \frac{5}{9} = 20°\text{C.}$$

To convert Fahrenheit readings to Reaumur.

Subtract 32 and multiply the remainder by $\frac{4}{9}$

$$e.g.\ 68°\text{F.} = (68-32) \times \frac{4}{9} = 16°\text{R.}$$

To convert Centigrade readings to Fahrenheit.

Multiply by $\frac{9}{5}$ and add 32.

To convert Reaumur degrees to Fahrenheit.

Multiply by $\frac{9}{4}$ and add 32.

To convert Centigrade to Reaumur.

Multiply by $\frac{4}{5}$.

To convert Reaumur to Centigrade.

Multiply by $\frac{5}{4}$.

Tables VI.–VIII., pp. 96–103, give comparisons of the various thermometrical scales in use.

The thermometers used in meteorological observations are of various kinds: Standard Thermometers, Ordinary Thermometers, Registering Thermometers, Self-recording Thermometers, and thermometers fitted for special purposes, such as Radiation Thermometers.

Standard Thermometers.

A standard thermometer is a thermometer made with especial care, and is employed for the purpose of testing from time to time the accuracy of thermometers used for ordinary observations. Standard thermometers.

The air thermometer is theoretically the most perfect standard instrument for the determination of temperature, but we need hardly mention it as it is not suited for use in ordinary meteorological observations.

Under these circumstances, it is hardly necessary to say that standard thermometers are usually mercurial, inasmuch as between the two fixed points on the scale to which allusion has been made above, and for a considerable range on either side of them, the expansion of mercury is almost absolutely uniform. The tubes themselves are selected with great care in order that they may be of uniform bore throughout, and that the size of the bulb (which is usually elongated) may be so proportioned to the calibre of the tube that a good open scale may be provided, as well as an extended range.

Every observatory of importance should possess one of these instruments, which should range from a point lower than any which is likely to occur in the severest frost, up to the boiling

Standard thermometers.

point of water,* in order to afford the possibility of testing at any temperature the thermometers used for ordinary observations. However, in places liable to very extreme cold, such as occurs in British North America, mercurial thermometers are not capable of indicating the lowest temperatures which are experienced, inasmuch as mercury freezes at the temperature of $-37°\cdot9$ F. For these places spirit thermometers must sometimes be employed, although for various reasons, such as the absence of uniformity in its rate of expansion, spirit is ill fitted for use as a standard thermometric fluid.

Construction of Standard Thermometers.—All standard thermometers must be graduated independently of any other thermometers, the tube being carefully calibrated and the graduation effected according to the principles laid down in the text books of physics. Moreover, owing to the fact that glass after having been fused does not immediately return to its natural condition of density, it is necessary to select for standard thermometers only such tubes as have been lying by for several years after being filled. The contraction of the bulb causes the thermometers to read too high, and this defect in a thermometer is called "the displacement of zero." After some time, however, the bulb ceases to shrink, and the indications of the instrument are thenceforward constant.

Standard thermometers should not be used for regular meteorological observations, but should be kept for the purpose of comparison with the other thermometers used for the observations.

Verification of thermometers.

Verifications.—All persons in purchasing thermometers, or in fact any meteorological instruments, should demand a certificate of their accuracy at various points on the scale as determined at some recognised scientific establishment, such as Kew Observatory; the addition to the cost of the instrument is very slight, and quite out of proportion to the security afforded to the purchaser. The usual Kew certificates give the errors at every ten degrees from 32° to 92°, but if required the instrument can be tested at higher or lower temperatures.

The limits of accuracy enforced at Kew for thermometers for the use of the Meteorological Office are as follow:—All thermometers are rejected for which the largest error at any point is greater than $0°\cdot3$ Fahrenheit, or for which any space of 10° F. is more than $0°\cdot3$ F. wrong.

Ordinary Thermometers.

These should be, of course, mercurial, and range from rather below the lowest to a little above the highest temperatures to be expected at the locality where they are used. Thus in the British Isles a range from about $-10°$ or $-15°$ to 100° is ample, but in more extreme climates the upper limit should be somewhat higher, while the graduation should extend in some cases even

* The reason of saying "up to the boiling point of water" is that every independent standard thermometer must at least extend to the full range of the two fixed points on the scale.

down to the freezing point of mercury, and spirit thermometers should be kept for use during the coldest period of the year.

Thermometer range.

All thermometers, without exception, should be graduated on the stem, and should possess a certificate of verification as already explained. Owing to the very general prevalence of the defect already referred to, the displacement of the zero, which only betrays itself after the lapse of some time, it is advisable, at least once a year, when opportunity offers, to determine the freezing point of water on the thermometers by immersing them in melting snow or ice as directed in the text books.

It is also necessary that great care should be taken to ensure that the quality of the earthenware, or other material, used for the slab to which the thermometer is attached, should be thoroughly good. If the earthenware be not properly glazed it is likely to absorb moisture, and then, when frost occurs, it becomes disintegrated, the surface scales off, and the whole becomes utterly useless.

Registering Thermometers.

These are thermometers which are provided with an arrangement which enables us to ascertain what has been the highest or lowest temperature to which they have been exposed in a given interval of time. There are a great many types of such instruments, but only a few of these, which are in general use, will be described.

Hours of observation of registering thermometers

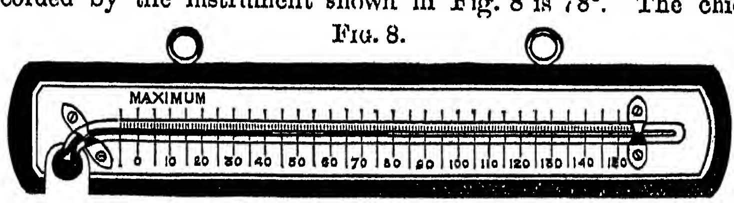
Under ordinary circumstances these instruments are read once a day. The observing hour ought to be midnight, if we wish to ascertain the highest and lowest temperatures experienced during the civil day, but as a midnight observation is not possible at ordinary stations, the Vienna Congress decided to recommend that these readings should be taken at the latest observing hour of the day. This hour is accordingly 9 p.m., for the British Isles, as will be seen by reference to p. 75.

Maximum Thermometers.—There are two kinds of maximum thermometers, which deserve nearly equal commendation, Phillips' and Negretti and Zambra's.

Phillips' Maximum Thermometers

In Phillips' thermometers the index is formed by a small portion of the mercurial column, separated from the main thread by a minute air bubble, and is pushed on before the column when it expands, but does not return with it when it contracts. It therefore rests at the extreme position to which it has advanced, and the end furthest from the bulb registers the highest temperature which has been attained. Thus the maximum temperature recorded by the instrument shown in Fig. 8 is 78°. The chief

Fig. 8.



objection to this form of thermometer is that in some cases the bubble of air is displaced, and the instrument then loses its registering properties and becomes an ordinary thermometer.

Negretti's Maximum Thermometer.

The plan of Negretti and Zambra's thermometer is simple, and the instrument is less liable to get out of order than the preceding. For these reasons it may be considered preferable for ordinary use. The registration is effected by the mercurial column itself in the following manner:—The bore of the thermometer tube is reduced in section close to the bulb in such a way that while the expansion of the mercury is sufficient to force the liquid past the obstruction, the cohesion of the metal is insufficient to draw it back again when the temperature falls.

Accordingly, if the instrument be set on any day so as to agree with an ordinary thermometer, and be examined after a time, when the temperature has risen above that which was prevailing when the setting took place, but which does not still exist, the amount of mercury in the tube above the contraction will represent the precise amount of mercury forced past the contraction when the temperature was highest, and thus will measure that temperature. The thermometer should be *slightly* inclined, bulb downwards, before reading, so as to let the separated portion of the column flow gently back to the contraction.

In order to set this thermometer, it should be held, bulb downwards, and shaken. The weight of the separated mercurial column will have the effect of causing all the superfluous mercury to return, past the contraction, into the bulb, and the instrument will soon come to indicate the same temperature as that of the air, and will therefore be ready for use again.

If the hands are not kept away from the bulb during the process of setting, it will not be possible to set the instrument so as to show the true temperature of the air.

Great care is required in making these thermometers to ensure that the contraction of the tube shall be neither too great nor too slight. If the former be the case, there will be difficulty in setting the instrument; if the latter, the indications will not be trustworthy, as some of the mercury may be drawn back past the contraction when the temperature falls.

In any case great care is required in placing a registering thermometer on its stand; each instrument usually requires to be hung at a certain angle, which generally differs very slightly from horizontality, but still it is necessary to determine by trial and error the precise position in which the instrument will best discharge its functions.

Minimum Thermometers.—There are two kinds of minimum thermometers in use in this country, Casella's and Rutherford's.

Casella's Minimum Thermometer.

Casella's thermometer is mercurial, and therefore cannot be used in countries where very low temperatures occur. It is very delicate and accurate in its indications, but requires so much care in management that it is generally admitted to be but ill-adapted for ordinary use. We shall, therefore, not describe it at length, but refer the reader to the maker's catalogue for an account of its principle.

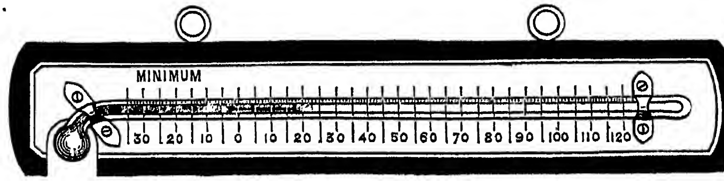
Rutherford's M[illegible] imum [illegible]uometer.

Rutherford's minimum thermometer is a spirit thermometer whose index is metallic and moves with a little difficulty in the

tube. It is entirely enveloped in the spirit, and the action is as follows :— **Rutherford's Minimum Thermometer.**

The index is allowed to run down to the end of the column by sloping the thermometer with the bulb uppermost and when so set is placed in a nearly horizontal position. If the temperature rises the spirit flows past the index without disturbing it. If, however, the temperature falls below that at which the instrument was set at

Fig. 9.



starting, the force of capillary attraction between the spirit and the index is such as to preclude its leaving the index dry, and accordingly this is drawn back with the spirit, its upper end being always flush with the extremity of the column while this is receding, and ultimately marking the lowest temperature reached by the column, as when the temperature rises the index is left behind again. The minimum temperature shown by the instrument in the figure is 17°.

Defects of spirit thermometers. These thermometers are liable to a serious defect, owing to the fact that a portion of the spirit becomes volatilized and is then condensed in the upper end of the tube, so that the continuous column is curtailed by a length of perhaps several degrees. It is to this liability to error of spirit minimum thermometers that some of the extraordinary discrepancies in reports of severe cold are probably to be attributed.

If a spirit thermometer reads lower than a correct mercurial thermometer close beside it, there is reason to suspect the existence of the defect above mentioned. The spirit is also liable to become broken into several detached portions, especially if the instrument is being transmitted from place to place ; or the index may be shaken entirely out of the spirit into the upper part of the tube. In all these cases the thermometer should be swung briskly to and fro several times, holding it bulb downwards, until all the liquid which may have been visible at the upper end of the tube shall have been dislodged. The instrument should then be placed in an upright position, bulb downwards, and left there for half an hour or so. This treatment will usually have the effect of restoring to the instrument its correctness of indication.

Sensibility of spirit thermometers. There is a great difference between mercury and spirit with regard to sensibility, the former liquid having a much lower specific heat and much higher conductivity than the latter. Accordingly a spherical bulb filled with spirit does not indicate sudden changes of temperature with nearly the same rapidity as one filled with mercury. This defect is obviated by making the bulb of the thermometer of such a shape that as large a surface of the spirit is exposed to the action of the air as

possible. Various patterns of minimum thermometers with forked or cylinder shaped bulbs, &c., have been brought out, which are quite as sensitive as mercurial thermometers of the ordinary form, and are strongly recommended for use, in preference to those of the usual pattern.

Self-recording Thermometers.

Thermographs. Various methods have been proposed for adapting to thermometers an arrangement whereby they shall record their own readings, either at frequent intervals or continuously, so as to avoid the necessity of close attendance of the observers.

Records at frequent intervals are obtained by the electrical thermographs, as such self-recording instruments are termed: In Theorell's and Van Rysselberghe's, which are among the best of these, the thermometer differs from ordinary thermometers, in that the tube is open at the upper end, and a wire is introduced into it, which, by a clock-work arrangement, is caused at frequent intervals to descend until it touches the surface of the mercury. As soon as contact is established, an electric current is set up and a record is obtained. The wire is then raised again and the contact is broken.

An example of the continuous method of record is the photographic thermograph, adopted by the Meteorological Committee at their observatories, which is described in their Report for 1867. In this instrument a bubble of air is introduced into the column of mercury, and this moves up and down with the temperature, as the bore of the tube is larger than in Phillips' maximum thermometer, in which the separated portion does not return towards the bulb on a fall of temperature.

A lamp is placed before the instrument and a photograph of the space occupied by the air bubble is taken on prepared paper, which is stretched on a drum and caused to revolve once in 48 hours.

In the thermograph in use at Greenwich, the light is allowed to pass through the open space in the column, above the mercury, so that the length of the photographic impression varies with the height of the thermometrical reading. This is a principle somewhat similar to that in use in the Kew Barograph, p. 26.

Thermometer Exposure.

The exposure of thermometers is confessedly one of the most difficult questions in Meteorology, and we are as yet far from a satisfactory solution of it. In fact, the readings of thermometers are so liable to be affected by other influences than that of the mere temperature of the air, that we are very likely, in avoiding some of these agencies, to expose the instruments to others.

It may be assumed as certain that the conditions of exposure for thermometers which will suit an insular climate like that of the British Isles, will not suit extreme climates like those of Canada or India.

In very cold climates many observers perforce adopt the exposure of their thermometers in a simple screen attached to the wall

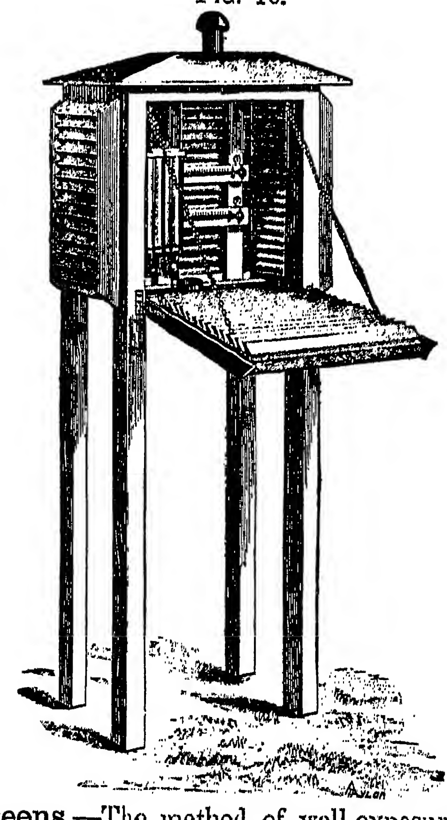
of the house, where the instruments can be read through a window without the necessity for the observer of going out of doors at each time of observation. This method is only a make-shift, but the choice lies between such observations and no observations at all.

Stevenson's Screen.—It is unnecessary to remark that a free exposure, whenever the same is attainable, is by far the best for thermometers, but there is a great difference of opinion as to the precise form of screen which is best suited for adoption. On the whole, for use in the British Isles, Stevenson's screen seems to be as good as any hitherto proposed, though it too is capable of improvement. This form of screen is shown in Fig. 10. The louvres are double, sloping in opposite directions, so that while there is access of the air to the inside, the radiant heat and rain are effectually excluded. Its chief defects are its small size, and its liability to be choked occasionally by drifting snow, owing to the closeness of the louvres which form the sides, which also checks the free circulation of the air round the instruments.

Thermometer exposure.

This screen should be erected on legs 4 feet high, and should stand over grass on open ground. It should not be under the shadow of trees nor within 20 feet of any wall.

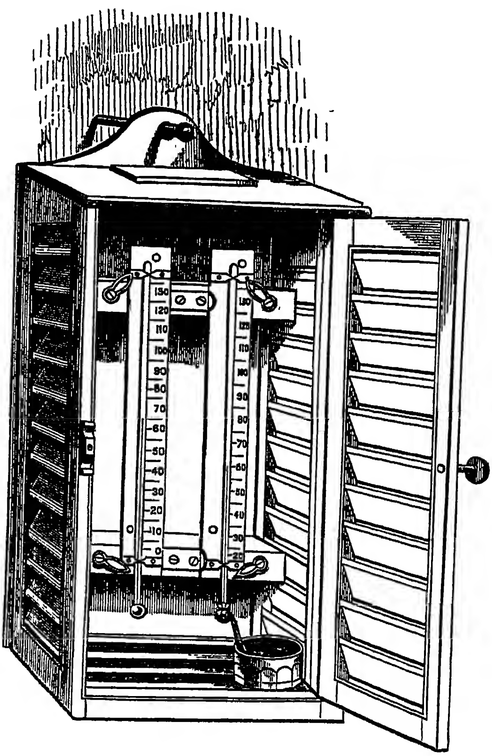
FIG. 10.



Wall Screens.—The method of wall exposure is necessarily adopted at several telegraph stations and in towns, when an open

Wall screen. space for a free standing screen cannot be obtained, and it has the merit of cheapness, and of some approach to accuracy. It is also the method adopted on board ship. A small covered case, Fig. 11, is placed at a height of about 4 feet from the ground on a wall which faces due north, if possible. In such a position it cannot receive the direct rays of the sun in these latitudes, except for a few hours in the early mornings and late evenings in summer. The screen should be fixed on holdfasts so that there may be a space of several inches between the back of the screen and the wall; care must, however, be taken that there is free circulation of the air about the screen, and that there are no walls or other objects in front which could reflect much heat to the instruments. The screen should also be carefully sheltered from the sun's rays. The readings of thermometers so exposed are found to differ from 0° to 5° (according to the size of the building, and the state of the weather) from those of similar instruments exposed in a Stevenson's screen in open ground. In fact this screen should never be used if there is a possibility of employing a free standing screen, such as that shown in Fig. 10.

FIG. 11.



A wall exposure of some sort or other is absolutely necessary for a thermograph, inasmuch as the apparatus for registration is of a delicate nature, and must be adequately protected against weather, and against changes of temperature, otherwise disturb-

ances will be introduced which may seriously interfere with the correctness of the record.

It is evident that the necessity of arranging the thermograph so as to correspond to some floor of a building precludes the possibility of being able to ensure that the bulbs shall be in all places at the same height above the ground, as it is not possible to erect special buildings for meteorological observatories at all stations.

Thermomètre fronde.

Sling Thermometer (*Thermomètre fronde* of the French).—In order to meet this difficulty about thermometric exposure, it has been suggested to dispense with the use of screens altogether, and to measure the temperature by means of a thermometer attached to a string, and swung round for about half a minute. By this method, *even in full sunshine*, a very close approximation to the true shade-temperature of the air may be obtained. This mode of determining temperature has not as yet been much used in England, but it seems advisable to mention it in this place.

Radiation Thermometers.

Radiation.

Practically the sun's rays are the only source whence heat reaches the earth's surface, and Radiation from the earth into space the only mode in which heat is again lost.

Any attempt to measure the intensity of these two forces must therefore be regarded *à priori* as of the greatest importance to meteorology. In practice, however, the irregularities arising from the distribution of heat by winds greatly complicate the problem of deducing the climate of any place from the relative effects of Solar and Terrestrial Radiation, especially in insular positions.

It is only in the interior of great continents that any great degree of regularity in the climate occurs, because there alone are the changes, in the main, directly due to Radiation.

Furthermore, as meteorologists have generally contented themselves with observing the climate actually produced in preference to troubling themselves with any attempt to gauge the forces which produce it, it will not be surprising to find that the solution of any such problem as that indicated seems almost indefinitely distant.

Scarcely any of the methods employed for measuring solar or terrestrial radiation are thoroughly satisfactory.

Solar Radiation.

Solar Radiation.—The best instrument hitherto brought into use for measuring solar radiation is known as the "blackened "bulb thermometer *in vacuo*." It consists of a sensitive thermometer (which is usually a maximum thermometer, for convenience of registration), having the bulb and one inch of the stem coated with dull lamp black.* The whole is then enclosed in a glass tube, of which one end is blown out into a bulb of about 2·25 ins. diameter,

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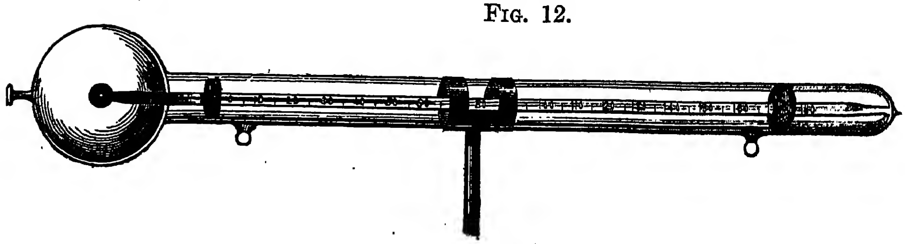
* The object of coating part of the stem is to prevent the temperature of the blackened bulb being lowered by contact with the cooler glass of the unblackened stem.

Solar Radiation.

enclosing the bulb of the thermometer, which is fixed in its centre. The glass jacket, so constructed, is then exhausted of air by a good air-pump and permanently closed.

It is evident that as the action of this instrument depends in some measure on the completeness of the vacuum, it is not sufficient simply to test the thermometer which is to be enclosed in the envelope. It is necessary to have some independent method of gauging the amount of rarefaction which has been attained. This may be done in various ways: Messrs. Negretti and Zambra introduce a mercurial pressure gauge into the vacuum, while Mr. Hicks has soldered platinum wires into the glass (Fig. 12), and tests the state of the vacuum by the passage of the electric light.

FIG. 12.



The instrument is then freely exposed to sun and air by fixing it horizontally at the same height above the ground as that at which the shade thermometers are placed. This is usually 4 feet. It must be at a distance from walls or trees or any objects which may obstruct or reflect the full rays of the sun. The bulb is usually directed to the S.E.

If, however, the thermometer be a maximum thermometer on Negretti's principle (p. 38) it may with advantage be placed in a vertical position with the bulb uppermost.

The reading of such an instrument depends on the elevation of the temperature at which equilibrium is established between the heat produced by the direct rays of the sun and the cooling produced by the radiation of heat from the bulb to the external jacket. The jacket has a temperature depending upon, and differing but slightly from, that of the air surrounding the instrument. It follows, then, that the excess of this temperature of equilibrium over that of the outer jacket is an *exact* measure, and its excess over that of the outer air is a closely *approximate* measure, of the power which the sun's rays, acting through glass, have exerted upon the bulb; hence, the following instructions:—

Rules for observing.

Observe the maximum temperature registered by the solar radiation thermometer, subtract from this the maximum temperature of the air in the shade, and the result indicates approximately the greatest amount of radiation which has occurred during the day.

It has also been suggested to expose alongside of the black bulb *in vacuo* a similar thermometer also *in vacuo*, but with its bulb bright, and to register the difference between the readings of the two instruments.

The result obtained by these readings is quite irrespective of the duration of sunshine, or of the sun's altitude. Both of these elements must be taken into consideration before the effect of solar radiation upon climate can be traced. The sun's altitude is of course known, but some good method of recording the duration of sunshine, or the total amount of heat received, is much needed.

Terrestrial Radiation.

Terrestrial Radiation.—All objects exposed to the sky radiate heat towards it. If the sky be overcast much of the heat thus radiated is returned, as the clouds, though generally colder than objects on the earth's surface, are very much warmer than space. Even if the sky be clear the vapour contained in the atmosphere has the power of retarding the escape of heat from the earth, consequently a dry climate is by far more favourable to radiation than a damp one.

As the effect of terrestrial radiation is most marked where the disturbing influence of wind is least felt, it is usual to place a thermometer intended to measure radiation upon the ground. A piece of good lawn grass is selected and a sensitive minimum thermometer suspended over it on wooden Y's, at the height of from one to two inches above the soil, so as to touch but not be buried in the blades of grass. The defect of the temperature so registered, below the minimum in the air, is taken as the amount of terrestrial radiation.

The indications of a thermometer so placed are much influenced by the temperature of the soil, from which it is more or less insulated, according to the length and thickness of the grass interposed, so that a thermometer over long grass reads lower than one over shorter grass, in the heat of summer as well as in winter. In severe frost, if the ground be not covered with snow, a thermometer placed upon short grass will fall very little below the temperature of the air, on account of the heat received from the soil. For this reason, whenever snow is lying, the radiation thermometer should be placed on its surface.

Moreover, it is found that a lower temperature is usually marked over a large grass plot than over a small one, because the cold air resting on the latter is liable, at the slightest breath of wind, to be replaced by that which has been resting on some surface which is a less powerful radiator.

Where no grass can be obtained the thermometer should be placed on a large black board laid upon the ground. Under any circumstances a board gives a better measure of terrestrial radiation than grass; a small groove may be cut in it to receive the bulb and prevent the thermometer from rolling.

It is much to be desired that some convenient method should be devised by which correct and comparable observations of radiation may be secured.

HYGROMETRY.

General Description of the Instrument.

There are various kinds of hygrometers, the observations of the amount of moisture in the air being taken in a direct, as well as in an indirect, manner.

The most important instruments for *direct* observations are Daniell's and Regnault's, both of which require the employment of ether to lower artificially the temperature of the instrument.

Direct Hygrometers.

Daniell's Hygrometer consists of two bulbs connected together by a tube. One bulb is of black glass, the other of clear glass and coated with muslin. The liquid within the bulbs is ether, which has been made to boil when the instrument was sealed, so that all air should be expelled. The instrument will then act in a similar way to Wollaston's Cryophorus, and if a difference of temperature be produced between the two bulbs all the liquid will be transferred from the warmer to the colder bulb.

The mode of taking an observation is the following:—The whole of the ether is caused to enter the black bulb, and a little ether is dropped on the muslin covering of the clear bulb. The evaporation of this ether lowers the temperature of this clear bulb, and causes the ether in the black bulb to distil over into the clear one. This process has the effect of lowering the temperature of the black bulb, and as soon as ever this reaches the temperature of the Dew point, the vapour in the air begins to be condensed on the outside of the black bulb, and dulls it by the formation of a ring of minute globules of water. The temperature at which this takes place is indicated by a thermometer which is placed inside the instrument, with its bulb within the black bulb.

Regnault's Hygrometer is rather more complicated than the foregoing. It consists of a glass tube silvered on the bottom and for a short distance up. The tube is intended to contain ether, and is closed at the top by a cork pierced by two holes. Through one of these a thermometer passes, so that its bulb reaches to the bottom of the silvered tube, while the other opens a communication between this tube and an aspirator or air-pump.

The mode of observing is to introduce some ether into the silvered tube, replace the stopper, and then, by mechanical means, withdraw the ether vapour from the tube. The temperature of the remaining contents of the tube falls quickly, and ultimately the vapour present in the air begins to be condensed on the silver as soon as the dew point is reached. The temperature at which this phenomenon takes place is indicated by the thermometer.

These instruments accordingly give the dew point by direct observation, but the latter is by far the more trustworthy. Both of them require very great care in manipulation, especially the former.

There are two great classes of *indirect* hygrometers, viz., organic hygrometers and the psychrometer, or wet and drybulb hygrometer.

Hair Hygrometers.

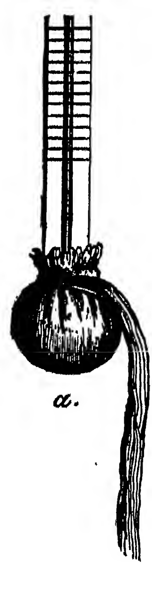
Organic hygrometers are instruments which indicate the amount of moisture in the air by the behaviour of some organic substance. Thus cords contract in wet and stretch in dry weather. The only hygrometer of this character worth notice is Saussure's hair hygrometer, which shows the humidity of the air by means of the alteration of length of a hair. Hair, conversely to cord, stretches when it is moist, and contracts when dry. This instrument is but little used in these islands, but as it has been generally recommended by the Vienna Congress, for use in extreme climates when the indications of the psychrometer are either uncertain or entirely astray, it seems necessary to allude to it here.

Wet and Dry Bulb Hygrometer.

Wet and Dry Bulb Hygrometer.—The psychrometer of August, or as it is usually called in this country, "Mason's," or the wet and dry bulb, hygrometer, is by far the most convenient instrument for use under ordinary circumstances. This is represented in Fig. 11, p. 42.

The instrument consists of two thermometers, the bulb of one of which is coated with muslin and kept moistened with water. The principle of its action is that, as long as the atmosphere is not saturated with vapour, evaporation will take place from any free water surface, such as the moist coating of the wet bulb. If then the air be saturated, no evaporation is possible, and the two thermometers, the dry and the wet bulb, will read alike. If the air be not saturated, the coating of the damp bulb will give off vapour, and the temperature of that thermometer will fall until a certain point is reached, intermediate between the temperature of the air and the dew point; below this temperature the wet bulb thermometer will not fall, unless the temperature of the air falls, or the air becomes drier, but it must be remembered that the temperature of this thermometer will begin to rise again if the muslin coating of the bulb begins to get dry, owing to a deficient supply of water, or if the supply be too copious and the coating too wet.

Fig. 13.



a.

The usual mode of regulating the supply is to keep a small reservoir of water close to the damp bulb, and to establish a connexion from the one to the other, by means of a few threads of worsted or lamp cotton, as shown in the figure. The worsted should be long enough to reach a few inches below the lowest part of the bulb, and should be carried down so as to dip in the vessel of water when it will act as a capillary syphon, and keep the bulb constantly moist.

The management of this instrument requires some special precautions. In the first place, the covering of the wet bulb must be very thin, else there is danger that true thermic equilibrium will not be established between the outside of the coating

Management of wet and dry bulb Hygrometer.

where the evaporation is going on and the actual bulb. In the second place, the supply of water must be very carefully regulated, so that the bulb shall be constantly moist, and yet not too wet. Accordingly we ought to have a more ample supply in dry weather than in damp, or we shall find that on a hot summer's day the worsted becomes perfectly dry, and no longer acts as a syphon, the bulb itself becoming dry; while if a sufficiency of water be provided to meet such an emergency, there will be a brisk drip going on from the damp bulb in damp weather, which is certainly wrong.

The cup, glass, or other small holder of water ought not to be under or too near the dry thermometer. The little reservoir should be placed at some distance on the off side of the wet thermometer, that is, as far as possible from the dry, which should not receive moisture from any source whatever. Of course if moisture be found on the dry bulb, this should be wiped and left for a while to assume the true temperature of the air. The water for the wet bulb should be either distilled or rain water, or, if this be not procurable, the softest pure water which can be had, to avoid the inconvenience of the deposit of lime, &c. on the bulb. The water vessel should be replenished *after*, or some *considerable time before*, observing; because observations are incorrect if made while the water is warmer or colder than the air.

The muslin and worsted should be well washed before being applied, and occasionally while in use. They should be changed once or twice a month, or even oftener, according to the quality of the muslin, &c., and the exposure to *dust* or *blacks*. Accuracy depends much on the care taken for cleanliness, and a proper supply of fresh water.

Management in frost.

The great difficulty with the instrument is found at a time of frost. The water on the worsted freezes, and the capillary action is at an end, so that the bulb soon becomes as dry as in hot weather. If then the temperature be below the freezing point it is obvious that water cannot be placed on the coating of the wet bulb without raising the temperature of the instrument. The thermometer will not be fit for an observation until the freshly-added water has become frozen and the temperature of the thermometer has ceased sinking. At such a time the evaporation will be going on from the surface of the ice, and the thermometer will act in the same way as if it had a damp bulb.

This shows us, however, that in winter it is quite impossible to maintain a *constant* supply of water to the wet bulb, and this form of hygrometer is practically useless for *self-recording* purposes in cold weather.

When the damp bulb is frozen it should be wetted, by means of a camel-hair brush or a feather, with some cold water taken from under ice, care being taken to raise its temperature as little as possible. After waiting a few minutes, the moisture will first freeze, then cool down to the temperature of the air, and finally the thermometer will fall a trifle lower than the dry one, and then the temperature of evaporation may be noted.

In time of hard and continued frost, if a coating of ice be allowed to form on the coating of the damp bulb, this will remain for several days before the bulb will become dry again.

In some rare cases, *e.g.* during thick fog or in very cold calm weather it may sometimes happen that the wet bulb reads *above* the dry bulb. This arises from the fact that when there is no loss of heat by evaporation its muslin coating prevents its indicating the temperature of the air as correctly as the unprotected bulb. In such cases the readings are to be considered as identical with each other, the air being perfectly saturated.

Theory of wet and dry Hygrometer.

The theory of the psychrometer has been very thoroughly investigated by Prof. Apjohn (Trans. R. I. A., Vol. XVII.), who gives the following equations:—

$$f' = f - 0.01147\,(t - t')\frac{p - f'}{30.}$$

Where f'' is the tension of aqueous vapour corresponding to the dewpoint.

f' is the tension corresponding to the reading of the wet bulb.

t is the temperature of the dry bulb.

t' " " wet "

p is the reading of the barometer.

The fraction $\frac{p-f'}{30}$ differs little from unity, and as it is multiplied by a very small factor the difference may practically be neglected, so that the formula becomes—

$$f'' = f' - \frac{t - t'}{87}$$

For temperatures below 32° this formula becomes—

$$f'' = f' - \frac{t - t'}{96}$$

These formulæ require the use of tables of Tension of Aqueous Vapour, and as it is troublesome to calculate afresh for each observation, tables have been compiled which give the dew point by inspection.

The best tables at present in English measures are Glaisher's (5th edition), which have been constructed empirically from direct experiments carried on at Greenwich, combined with Regnault's tables of the Elastic Force of Aqueous Vapour, &c.

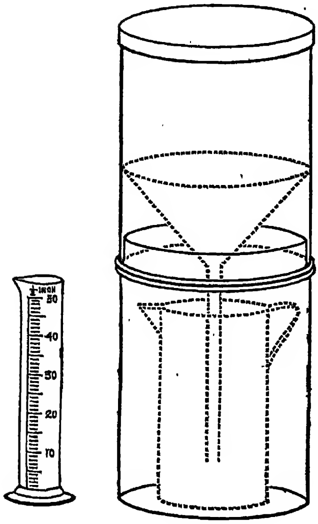
These tables are reasonably accurate for the conditions usually prevalent in the United Kingdom, but they are entirely insufficient when we have to deal with very dry climates, such as those sometimes found in India. For such circumstances accurate hygrometrical tables in English measures are yet wanted.

THE RAIN GAUGE.

Rain gauge.

Form and Exposure of Gauge.—There are numerous patterns of rain gauges, but the best for general use is that shown in Fig. 14. It has a circular collecting funnel, the rain is caught in a can, and measured in a graduated glass. The upper edge of the funnel is fitted with a vertical rim about six inches in depth, with a stout brass ring, ground to a knife edge on top, which will preserve its shape perfectly, and entirely prevent insplashing of rain-drops. The object of the addition of this rim is to catch snow, as will be explained below. Great care should be taken to insure that the mouth of the funnel is not dented, as if the area be not a true circle, the full amount of rain will not be collected. The sole reason for preferring circular gauges to square ones is that the latter get more easily out of the shape than the former.

Fig. 14.



There is some difference of opinion as to the proper area of the collecting funnel. The Meteorological Office employs a diameter of 8 inches. Mr. Symons recommends, for ordinary stations, owing to their cheapness, 5-inch gauges, but it has been shown by most carefully conducted experiments that the difference in indications between gauges of various apertures, ranging from 3 ins. to 24 ins. in diameter, is very small, hardly exceeding one per cent.

The gauge should be set up in a well-exposed position, where it will not be sheltered by trees, buildings, or high walls on any side. It should be placed on the ground, perfectly level, and be firmly fixed so as not to be blown over. In some cases it is advisable to sink the lower part of the cylinder a few inches into the ground. The height of the rim above the ground and above the Mean Sea Level should be given, the best height for the former being 1 foot, except in places liable to very heavy falls of snow. The angle subtended in each azimuth by the nearest obstacle, such as a building or a tree, and its true bearing from the gauge should be carefully measured and noted in the register.

The gauge should never, under ordinary circumstances, be

placed on a roof or at any considerable elevation above the ground, as in such cases the amount collected will be less than that which would have been recorded had the gauge been on the ground. Nevertheless a roof exposure is better than such a ground exposure as is sometimes the only one attainable in town gardens, if the space be very confined.

The observer should remember never to collect the rain in the measuring glass supplied with the gauge, instead of using the proper can for the purpose. If this be done in winter there is a risk of breaking the glass if frost should set in after rain has fallen. However, a large glass bottle, *e. g.*, a Winchester quart bottle, may with advantage be used instead of the copper collecting can, excepting in winter, inasmuch as the evaporation from a bottle is less than from a can. Collector.

Measurement of Rain.—The gauge should be examined every day at 9 a.m., and the amount found in it entered in the Register as having fallen on the *previous day*, inasmuch as if we measure at 9 a.m. to-day, it is probable, under ordinary circumstances, that more of the rain in the gauge will have fallen during the 15 hours of the previous day, up to midnight, than during the nine hours from midnight to 9 a.m. Measurement of rain.

The measurement of snow or hail is to be effected by thawing the quantity collected in the gauge, and measuring the water which results therefrom. This method of measuring the snow is not very satisfactory, as if there be much wind the snow will be blown out of the gauge, and the measurement will thus be rendered entirely untrustworthy To meet this difficulty the rim is sometimes put on the top of the funnel of the gauge, as explained above, and this renders it more difficult for the snow to be whisked out of the gauge. If the gauge be not fitted with this arrangement the best plan is to take the outside cylinder of the gauge, which has the same diameter as the funnel, and invert it over snow, lying level, where its depth seems to be nearly uniform and of about the average amount, and to collect the solid cylinder of snow, thus cut out, and melt it. This proceeding ought to give the quantity which would have been collected in the gauge if the snow had not been blown out of it, but the results are not absolutely satisfactory. A good method of thawing the snow quickly is to add to it a measured quantity of warm water, and subtract this quantity from the resulting volume of water. It is said that this process gives rather too small an amount, but the process of allowing the snow to thaw slowly in a warm room takes too much time. Measurement of snow and hail.

It is sometimes recommended to measure the depth of the snow and enter a certain fraction of this depth as the amount of water which the snow would yield if thawed. It is generally said that a foot of snow gives an inch of water, so that one-twelfth of the depth of the snow in inches would be the amount of rain corresponding to a given fall of snow. This estimate is, however, only a very loose approximation, as the layer of snow is not always of uniform density.

Entry of rain, etc.

If snow is lying for more than a day the observer should measure every morning the depth of the snow at some place where it is lying evenly, and has apparently not been drifted, and should enter the depth in the "Remark" column.

The character of the precipitation when other than Rain should always be stated in the column of Remarks, and the appropriate symbols used to indicate it. "Hail" should only be entered when the stones are hard; the soft stones ("Graupel" in German), like small snowballs, which fall in dry weather in spring are to be specially noted.

The time of occurrence of the precipitation is to be noticed by the addition of *a* (a.m.) or *p* (p.m.) to the symbol employed, and the duration of the fall in hours, as estimated by the observer, is to be inserted in the proper column.

EVAPORATION.

Evaporation is a subject which has not as yet received as much attention as it deserves, but this is partly owing to the great difficulty which exists in making any accurate observations on it. The amount of moisture removed from a water surface by evaporation depends on the degree of humidity of the air immediately in contact with that surface, and also on the rapidity with which that air is renewed by the action of wind. Atmometers.

The ordinary method of measuring evaporation, by means of an open gauge or "atmometer"* filled from time to time with water, the decrease in depth of which during a given interval of time gives the volume of water removed by evaporation, is a very rough mode of observation. In the first place, rain falls into the vessel, and account must be taken of its amount, while during a heavy shower much water will be lost by splashing. Of course, however, arrangements can be made to shelter the instrument from rain.

Moreover, the rate at which the air in immediate contact with the surface of the water in the gauge is renewed, *i.e.*, the free access of the external air to the surface of the water, depends on the depth at which this surface stands below the rim of the gauge. Hence it becomes necessary to introduce some contrivance to maintain this level constant.

Various atmometers have been devised of late years by Prof. von Lamont, M. Dufour, Dr. A. Mitchell, Prof. Osnaghi, and others, but none of these has as yet met with general acceptance, so that it does not seem necessary to describe them in detail.

The three first named measure the evaporation by the volume of water removed, and must therefore be useless during frost; the last indicates the evaporation by the loss in weight of a vessel containing water, and it can therefore give indications in winter.

There is this uncertainty about evaporation that all the experiments to which reference has been made relate to that taking place from an exposed water surface of a, comparatively speaking, infinitesimally small area, and can therefore have but a very partial applicability to the conditions occurring in nature. There are two main reasons for this statement. Firstly, the proportion of the surface of the land on the earth which is covered with lakes and rivers is very limited, and the experiments above indicated throw no light on the evaporation from the soil. Secondly, the evaporation from the surface of a small atmometer erected on the ground, with comparatively dry air all around it, is certainly very different from that which would take place from an equal area in the centre of a large water surface, such as a lake. Uncertainty about the observations.

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* Perhaps Leslie's term "atmidometer" is more classically correct, but "atmometer" has the advantage of being shorter without being absolutely incorrect. Such mongrel words as "evaporometer" are inadmissible.

Evaporation.

Uncertainty about the observations.

It is of course easy to make experiments on the evaporation from the soil by means of a balance atmometer, but in order that these should possess a practical value, the investigation must be extended so as to include a wide variety of soils, &c., &c. As regards the second point which has been raised, it is recommended by the Vienna Congress to erect atmometers in the centre of water surfaces; but it is not a very easy matter to conduct such experiments with accuracy, owing to the risk of in-splashing from waves.

The subject is one of very great importance, especially as regards its connection with rainfall and water supply, and well deserves especial attention, but it cannot as yet be said that the results hitherto obtained merit much confidence as regards their applicability to the evaporation occurring in nature, owing to the exceptional manner in which the observations have been made.

WIND.

Various instruments have been proposed for the registration of Wind, according to whether it be wished to obtain a record of the Force or Pressure, or of the Velocity. There is comparatively little trouble in obtaining a record of the Direction.

Pressure Anemometers.—The oldest pressure anemometer is Lind's, which consists of an inverted syphon tube, half filled with water, and graduated on the longer arm. The force of the wind is measured by the height of the column of water which the wind is able to maintain in the longer arm above the level of the water in the shorter. The instrument is held in the hand, and the bell-mouthed opening of the shorter leg of the syphon, which is bent at a right angle, is turned to face the wind. Such an experiment is necessarily very rough.

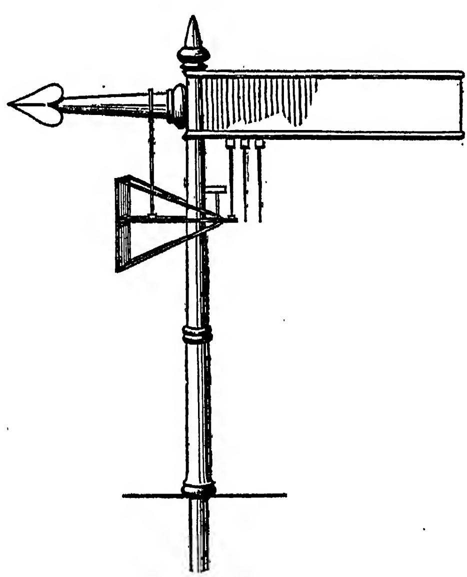
Pressure Anemometers.

Lind's.

Until recently the most perfect pressure anemometer was Osler's (Fig. 15), in which the force of the wind is measured by the distance to which the pressure plate is driven back on the springs. This motion is communicated to a pencil, and the record preserved on paper.

Osler's.

FIG. 15.



The chief objection to this instrument arises from the use of springs which, from their continual exposure to weather, cannot always preserve the same strength and elasticity, and whose condition must therefore considerably influence the results.

A more recent instrument of this class is Cator's, in which the resistance is furnished by a system of levers instead of springs.

Pressure Anemometers.

Cator's.

These consist of two eccentric curves of different sizes rigidly connected together and revolving on the same axle, of which the curvatures decrease respectively in opposite directions, so that the effect is doubled. Round the larger one a cord is carried, from which hangs a fixed weight. Round the smaller one a chain is passed, which is connected directly with the pressure plate and also with the recording pencil.

The chief value of this apparatus consists in its close proximity to the recording pencil and in the fact that the resistance is always the same, as every part of the instrument, except the pressure plate, is under cover and free from exposure to the weather. Another peculiarity of this instrument is that the plate is furnished with a conical back, so as to diminish the error arising from the formation of a partial vacuum behind it in strong winds.

Uncertainty of results.

The chief difficulty about the use of such instruments as these consists in the fact that neither the results obtained from the different instruments with the same size of plate, nor those from the same instrument with pressure plates of different sizes, show as close an accordance *inter se* as might be wished: so that we are unable to say what is the best size to adopt as the normal plate; that usually employed is one square foot.

Notwithstanding this objection, pressure anemometers are of great importance as being the only instruments at present which can give us any record of the force of individual gusts of wind or of any sudden changes.

Wild's pressure gauge.

The Vienna Congress has recommended the introduction of Professor Wild's pressure gauge which is in use in Russia and Switzerland. This consists of a rectangular plate hung on hinges on a horizontal axis. The angle which this makes with the vertical indicates the force of the wind. This instrument gives sufficiently accurate results for light winds, but fails in the case of strongish winds, a plate which is light enough to mark the differences between forces 1 and 2 of Beaufort's scale (p. 58), will be kept in a nearly horizontal position *by even a moderate breeze*, so that there will be no perceptible difference in the indications for forces 6 or 7 and those for forces 10 or 11.

Robinson's Anemometer.

Velocity Anemometers.—Of velocity anemometers the only form practically in use is Robinson's, which is described in the Transactions of the Royal Irish Academy for 1850.

The velocity is measured by the rate of revolution in a horizontal plane, about a vertical axis, of 4 hemispherical cups fixed to the extremities of the arms of a cross. The motion of the axis is transmitted by gearing to the recording portion of the apparatus, which may be either a system of dials, which must be read off at definite intervals, or an arrangement for marking each mile of wind on a strip of paper moved by clock-work; or, finally, as in the full-sized anemographs, a pair of brass tracers which mark the velocity continually on metallic paper, stretched on a drum, which revolves once in 24 hours. In these latter instruments the direction is continuously recorded by the tracers in a similar manner to the velocity, the moving power for the direction tracers being a double windmill vane.

Theoretically the velocity of rotation of the cups in Robinson's anemometer is independent of the length of the arms or the size of the cups; but practically it is found that two instruments of different sizes do not give similar results, and most, if not all, of the smaller instruments which are in use yield results falling 15 or 20 per cent. below what ought to be the correct indication, while the larger ones give figures slightly above the correct results. This subject, however, urgently requires a closer investigation. **Robinson's anemometer.**

There is, however, an inherent difficulty about all anemometrical measurements, whether of pressure or velocity, in that they are most seriously affected by the position of the instrument. If it be attached to, or even erected near, any large building, or if there be high trees in the vicinity, it will indicate much less wind than if it were in a perfectly open country, and the results of recent experiments have thrown much doubt on the possibility of comparing, with any degree of minuteness, anemometrical data from different stations. **Effect of position on anemometrical indications.**

This fact alone is sufficient to condemn nearly all the determinations of absolute velocities hitherto made with small anemometers by private observers, even though the instruments were perfectly correct.

Various instruments have been devised, employing methods of electrical registration of the velocity, and allowing of the cups, &c. being erected at a distance from any buildings, but it seems all but impossible to erect the instrument so that it shall be removed out of the sphere of the disturbing action of the irregular surface of the ground on the current of air passing over it, so that all we can say is that it at present appears that the results from each station must be compared *inter se*.

The oldest method of observation of wind is by sensation or by estimation. This is necessarily somewhat rough, as it must depend to a very great extent on the individual observer. Nevertheless, it is the only mode of obtaining wind observations at the majority of stations, and with experience can yield very useful results. **Estimation of wind force.**

Sir F. Beaufort, when in command of H.M.S. "Woolwich," in 1806, devised a scale from these estimations (given in the subjoined table), having relation to the pressure of the wind on the sails of a ship, which has since been very generally adopted, in lieu of the former classification of the respective grades of force by words such as "Light Breeze," &c.

The scale of velocities added to the table has been determined in the Meteorological Office, but it must be considered as merely provisional.* It has been deduced from the indications of well-exposed anemometers on the coast during the prevalence of winds from the sea. It is hardly applicable to ordinary land stations, nor to those on the coast when the wind blows off the land, in which cases the velocity corresponding to a given force is much

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* The justification of the table will be found in a paper contained in the Quarterly Journal of the Meteorological Society, Vol. ii. p. 110, "An Attempt to establish a Relation between the Velocity of the Wind and its Force," by Robert H. Scott, F.R.S.

Relation between velocity and force of wind.

smaller, owing to the retardation of the *general motion* of the air by the inequalities of the surface of the ground, while the force is naturally estimated from that of the *gusts*. In fact, the steady pressure of a wind at sea gives a higher velocity than the uneven force of the same wind on land.

In all cases it must be remembered that the velocity being recorded as the number of miles of wind which have passed over the anemometer during a whole hour, that of an individual gust will often be far higher, and that of a lull much less, than the figure here given.

It is quite obvious that the nautical part of this table is all but unintelligible to a landsman, but still it is advisable to give it, as it seems to stand a better chance of general adoption than any other scale.

The equivalent velocities according to the metric scale, *i.e.*, in metres per second, may of course be obtained by multiplying the figures in the last column by the factor 0·447.

Force.	Beaufort Scale.			Velocity. English Miles per Hour.
0	Calm			3
1	Light air, or just sufficient to give steerage way			8
2	Light breeze	or, that in which a well-conditioned man-of-war, with all sail set, and "clean full", would go in smooth water from	1–2 knots	13
3	Gentle "		3–4 "	18
4	Moderate "		5–6 "	23
5	Fresh "	or that to which she could just carry "in chase," "Full and by"	Royals, &c.	28
6	Strong "		Single-reefed topsails or top-gallant sails.	34
7	Moderate gale		Double-reefed topsails, jib, &c.	40
8	Fresh "		Triple-reefed topsails, &c.	48
9	Strong "		Close-reefed topsails and courses.	56
10	Whole gale, or that with which she could scarcely bear close-reefed main-topsail and reefed foresail.			65
11	Storm, or that which would reduce her to storm-staysails			75
12	Hurricane, or that which no canvas could withstand			90

Since Admiral Beaufort's time there has been a great change in the rig of merchant ships owing to the introduction of double topsail yards; it therefore seems desirable to add to Beaufort's scale a statement of the amount of sail which his ship would have been able to carry, had she been rigged with double topsail yards. The change would only affect forces 6, 7, 8, 9, and 10, which would then read as follows:

Force 6. Top-gallant sails.
" 7. Topsails, jib, &c.
" 8. Reefed upper topsails and courses.
" 9. Lower topsails and courses.
" 10. Lower maintopsail and reefed foresail.

As regards the Direction of the wind it is hardly necessary to observe that this should always be given according to *true* and not to *compass bearings*. The amount of Variation of the compass in the British Isles being, roughly speaking, two points to the westward, we get the following table for the conversion of directions observed by compass in the United Kingdom to approximate true bearings.

Reduction of compass to true bearings.

Compass bearings	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
True bearings	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW

ATMOSPHERIC ELECTRICITY.

Electricity.

Although observations on Atmospheric Electricity are not called for from ordinary observers, it may not be amiss to give some notes on the subject in order to direct more attention to it than it has hitherto obtained.

The occurrence of Lightning and Thunderstorms should be noted in the "Remarks," column, as directed at p. 72; but in addition to these indications of great electrical disturbance taking place in the atmosphere, it is desirable that observations should be made upon the electricity existing in the air under ordinary circumstances, so as to determine, firstly, whether it is positive or negative, and, secondly, what is its intensity.

Electroscopes.—The simplest instruments of this nature, viz., the Gold Leaf, Bennett's and Bohnenberger's, are sufficient to show the nature of the electricity present in the air, but it is always found that very little electricity can be observed near the ground, and in order to obtain satisfactory indications, the conductor of the electroscope should be brought into contact with the air at some distance from the earth's surface, by means of a collector.

Collection of electricity.

Collectors.—A simple rough method of doing this is to shoot a metallic arrow upwards into the air, the arrow being tied to one end of a conducting string, the lower end of which carries a ring which rests upon the electroscope. The arrow being shot upwards, the electroscope will be found to be electrified, as it mounts; and when the ring leaves the plate, the instrument will indicate the state of electrification of the air at that point where the arrow is at the time.

This manner of observing is simplified by substituting a long conductor reaching upwards; a gilded fishing rod may be employed, its lower extremity being insulated.

The usual method employed, however, is Volta's, in which the electricity is collected by means of a flame, burning at a height, either in a lantern hung to a mast, and connected to the electroscope by a wire, or, by a slow burning match, attached to the top of a long metal rod.

The electricity of the air, in the neighbourhood of the flame, by its inductive action upon the conductor, causes electricity of the opposite nature to accumulate at the upper extremity, where it is constantly carried off by the convection currents in the flame, leaving the conductor charged with electricity of the same kind and potential as the air.

The principle of Volta's method has been made use of by Sir W. Thomson in his water-dropping collector, now employed in observatories, and found to be extremely suitable for the observa-

tion of atmospheric electricity, in connection with his electrometer. Collection of electricity.

A copper can is placed on an insulating support, which may be of ebonite, having the surface thinly coated with paraffin; or of glass, surrounded with pumice stone impregnated with sulphuric acid. From the can a small pipe projects a considerable distance into the air, and terminates in a fine jet. The can being filled with water, and the tap which opens into the jet turned on, a small stream of water is allowed to flow out, care being taken that it is so small that it shall break into drops immediately after leaving the nozzle of the tube.

In half a minute from the starting of the stream, the can will be found to be electrified to the same extent as the air at the point of the tube.

This collector cannot be employed during the time of frost, owing to the freezing of the water in the jet pipe. At such times therefore, and when observations are to be made with a portable instrument, a slow burning match should be used. Sir W. Thomson recommends for this purpose blotting paper, steeped in a solution of nitrate of lead, dried, and rolled into matches.

Position of Collector.—Since electrical density is greater on projecting surfaces, and less on hollow surfaces, than on planes, the collector should not be near trees, or houses, nor within a closed space.

Electrometer. — This instrument, designed by Sir W. Thomson, is of two kinds:

1st. The Quadrant, or modified Divided-Ring Electrometer, for observatory use.

2nd. The Portable Electrometer.

1st. **Quadrant Electrometer.**—This consists of a needle of thin sheet-aluminium, cut so as to resemble in form a figure 8 with the hollows filled in, carrying above it a small light mirror, weighing only a fraction of a grain. This is suspended from its centre by two fine silk threads, the distance between which can be varied at will. Quadrant Electrometer.

The needle swings horizontally inside a shallow cylindrical brass box, which is cut into four quadrants, each insulated separately by glass supports, but connected alternately by thin wires.

Each pair of quadrants is also connected to a stiff wire passing through the case of the instrument, to form the two electrodes, or terminals, for the attachment of the collecting and earth wires.

The base of the electrometer contains a Leyden jar, partially filled with strong sulphuric acid, and a platinum wire, hung from the lower surface of the needle, is made to dip into the acid.

A lamp and a divided scale are placed about a yard in front of the instrument, and the light shining through an aperture in the frame of the scale, is reflected by the mirror on the scale, where

Quadrant Electrometer.

the position of the image of a wire stretched across the hole can be accurately observed.

If the electrometer be used as a self recording instrument, a drum carrying photographic paper, and maintained in rotation at a uniform rate by a train of clockwork, is substituted for the divided scale, and the aperture reduced so as to form a mere dot of light on the cylinder.

In order to make use of the instrument, the needle must be charged, with electricity; this is done by bringing a small electrophorus, which has been previously well rubbed, into contact with a wire (charging electrode), dipping into the sulphuric acid at the bottom of the Leyden jar.

One of the electrodes connected with the segments is then joined by means of a wire to the water-dropping collector, and the other placed in communication with the earth through a wire attached to a gas pipe, or similar conductor. It will then be found that the electrometer needle will be deflected either towards the one side or the other, according as the electricity of the atmosphere is of the nature to repel or attract it, and the extent of repulsion, as measured on the scale, is proportional to the amount of difference of potential between the atmospheric and terrestrial electricities.

As the delicacy of the instrument is also affected by the extent to which the needle is charged, it is necessary that this charge should always remain constant. Although the sulphuric acid, by drying the air in the interior of the instrument, prevents the rapid loss of the charge, yet with the best jars a slight per-centage escapes every day, and to restore this loss, an auxiliary apparatus for the generation of electricity, termed a *replenisher*, is fixed inside the case, by turning which the charge can be restored to its original potential. This is indicated by a small gauge fixed to the top of the instrument.

The Gauge.

The Gauge.—The gauge is a light lever made of thin aluminium, one end of which is widened out, so as to form a surface of about a square centimetre in area; the other end carries an index, moving in front of a small scale. The plate forming the extended end of the lever is repelled by another plate, similarly electrified, fixed to the top of the instrument, which, being in metallic connection with the sulphuric acid of the Leyden jar, is charged to the same potential as the indicating needle.

The position of the index, when the electrometer is properly charged, being therefore once determined, it is easy, by giving a few turns to the replenisher at any time, to bring the potential of the charge of the instrument up to its original value.

Under ordinary circumstances it is found desirable to perform the replenishing operation at least once daily.

The scale of the Instrument.—The scale value of each

instrument must be experimentally determined, and should any change be made in the electrometer itself, either by replacing the threads which suspend the needle and mirror, altering their distance apart, or varying the adjustment of the gauge, a re-determination of the scale value must be made.

Scale of Electrometer.

In order to perform this operation a galvanic battery is needed; one of constant intensity should be used. Sir W. Thomson recommends Daniell's. The battery being charged and placed on an insulating support, the wire leading from the water-dropping collector is disconnected, and a wire from one terminal of the battery attached to the electrode of the instrument. The amount of deflection of the needle is then observed upon the scale, and noted. Contact is again broken, the electrode joined to the earth wire, and the scale read.

By repeating these observations several times, and varying the number of cells forming the battery, the value of the divisions of the scale can be determined.

Knowing the electric motive force of the cell employed, the indications of the electrometer scale may be converted into terms of the absolute unit of force or "volts."

Portable Electrometer.

Portable Electrometer.—The portable electrometer is a small instrument contained in a cylindrical brass case, 3·3 inches in diameter, 5 inches in height. It consists of a small glass Leyden jar, in the interior of which a gauge is placed, similar in construction to the one already described, as fixed to the quadrant electrometer, but inverted. The tinfoil is removed from both surfaces of the glass opposite to the index, in order to permit of its being viewed through the aperture; but in order to maintain the electrical potential uniform, a double screen of thin wire fences is introduced between the index on the lever and the glass through which it is observed.

The plate or disc opposed to the extended end of the indicating lever is attached to an extremely delicate and accurately constructed screw, by which it can be raised and lowered with the utmost nicety, and so brought nearer to, or removed further from, the lever. The distance through which it is moved is measured with the greatest exactitude by means of an index attached to the screw, which moves over a scale and shows the number of complete rotations, whilst a divided circle fixed to the axis indicates the parts of a turn.

An insulating medium is interposed between the disc and its elevating screw, so that the electrical condition of the former is not affected by the observer touching the screw.

A wire from the disc places it in connection with an electrode projecting through the cover of the instrument, the aperture being properly protected against the entry of wind or rain, and this electrode, when the instrument is in use, carries a burning match collector, as described on page 61.

Pumice stone saturated with sulphuric acid is placed in leaden trays in the interior of the instrument for the purpose of drying

Portable Electrometer.

the contained air, and it is necessary to remove it frequently, as often as the acid becomes hydrated, and supply fresh.

In order to use the portable electrometer it must first be charged; this is done by means of a small electrophorus, a charging rod being let down for the occasion through a hole in its roof. This charge should be negative.

The amount through which the disc must be moved to bring the lever index to its proper position after charging, is read by means of the scale and micrometer screw.

The charging rod removed, and the chief electrode connected with the outer case of the instrument, which itself is in connection with the earth; either through the observer, in whose hands it is held, or by a wire; if the index is again brought to zero, it is placed on an insulating support, and another reading of the scale made. The chief electrode is again insulated, then the collector put on and the match lighted. After a short time the index is again observed, and the disc moved until it is brought into its normal position, when the micrometer and scale are read.

In order to determine the scale value of the instrument, a battery must be employed as described above, p. 63.

Peltier's Electrometer.

Peltier's Electrometer.—Another form of instrument which is very highly recommended is Peltier's electrometer, which has been used for more than 30 years at Brussels by the late M. Quetelet, and for upwards of 20 years at Utrecht. The instrument is described in the *Annuaire Météorologique de France*, 1850, p. 181, and in the report of the British Association, 1849, Transactions of Sections, p. 11.

OZONE.

The subject of Ozone is frequently mentioned as one deserving of notice at meteorological stations, but up to the present time it seems advisable to abide by the opinion expressed by the Vienna Congress:—

" The existing methods of determining the amount of ozone in
" the atmosphere are insufficient, and the Congress therefore recom-
" mends investigations for the discovery of better methods."

CLOUDS.

We have hitherto spoken of the several observations which demand the use of instruments for their registration, but there is an extensive class of phenomena which cannot be recorded instrumentally, but of which it is necessary to take careful notice owing to their importance as indicating changes which are in progress in the atmosphere. Of these without doubt the most important are Clouds.

The following explanation of the different forms of cloud represented on the accompanying Plate has been prepared principally from the works of Luke Howard, whose definitions are given in inverted commas at the beginning of each description :—

UPPER CLOUDS.

The clouds belonging to this class are considered, on good grounds, to be frequently composed of particles of ice, inasmuch as the phenomena of halos, &c. are produced by them, and these can only be explained by the refraction of the rays of light through ice crystals. Upper clouds.

Fig. 1. **Cirrus** (cir.). "Parallel, flexuous, or diverging fibres, " extensible by increase in any or in all directions."

This is the very lofty cloud which looks like hair, thread, or feathers, and, when curved in form, is often called 'Mare's tails.' It frequently moves in a direction differing from that of the wind at the earth's surface, but its motion often appears to be so slow that it is very difficult to ascertain it correctly without watching for a very considerable time so as to mark its motion over some *fixed* object, but the importance of the observation makes it very desirable that special attention should be devoted to it.

Anything peculiar in the shape of *cirrus* clouds should be noted, as well as the point from whence they radiate, and the relation between their longitudinal extension and the direction in which they are moving. It should also be noted if they are more developed in one part of the sky than in another.

Fig. 2. **Cirro-cumulus** (cir.-c.*). " Small, well-defined round- " ish masses in close horizontal arrangement or contact."

This is also a high cloud, though usually at a lower level than the *cirrus*. It differs from the *cirrus* in being more globular in form, as it consists generally of small detached rounded masses, like a flock of sheep lying down, or like the markings on a mackerel, whence the name "Mackerel sky." It is sometimes softer than those shown in Fig. 2, and when seen at lower levels it may be difficult to distinguish these clouds from small *cumuli*. In such cases the fact should be noticed in the "Remarks" column.

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* Note.—The second part of the contraction has been reduced to one letter, because it is found that in practice the hyphen has frequently been left out, so that cir.-cum. was understood as *cirrus* and *cumulus* instead of *cirro-cumulus*. This error has been common to all the contractions.

Upper clouds.

Fig. 3. **Cirro-stratus** (Cir.-s.). "Horizontal or slightly inclined masses, attenuated towards a part or the whole of their circumference, bent downward or undulated; separate, or in groups consisting of small clouds having these characters."

This cloud is usually generated by increased condensation on the *cirrus* already formed, which consequently sinks to a lower level.

The first part of Howard's definition seems to be well represented by the upper portion of Fig. 3, in which the clouds are like sheets thinning out at their edges, while the latter part is clearly shown by the small light-coloured clouds at the bottom of the figure.

When bad weather is approaching the cloud increases in compactness and density and sinks to a lower level, at times entirely intercepting the direct rays of the sun or moon and presenting the appearance of a uniform sheet overspreading the sky.

Such uniform sheets* have generally been classed as *cirro-stratus*, but the observer should enter a special note of their occurrence in the "Remark" column, so that there shall be no risk of confusion between this appearance and that of the true *cirro-stratus*. This is the more necessary inasmuch as when the cloud sinks to a yet lower and lower level, it assumes more and more the character of the lower stratum, becoming a vapour cloud instead of an ice cloud.

Anything peculiar in the appearance of the cloud should be noted specially, as "cir.-s. high and hard," or "cir.-s. low and soft." Clouds are seen at all levels between the highest *cirrus* and the lowest *stratus*, so that it is often difficult to determine whether a particular sheet or layer of cloud belongs to the upper or the lower system. In such cases the observer will be greatly assisted by remembering how the clouds have become formed, whether by the gradual subsidence of the highest forms, or by the ascent of the lower clouds.

LOWER CLOUDS.

The clouds belonging to this class are usually composed of particles of condensed vapour or "bubble steam," *i.e.*, of water, not of ice. When they are interposed between the earth and the sun or moon, they dim or intercept the light entirely, without giving rise to halos or coronæ.

Fig. 4. **Stratus** (Str.). "A widely extended continuous horizontal sheet, increasing from below upward."

This is a sheet or layer of cloud, of uniform thickness generally. It has but little variety of light and shade, and belongs essentially to the lower regions of the atmosphere, so much so that Howard speaks of it as "Ground Fog," the cloudy formation which spreads over low grounds in the evening, and disappears as soon as the temperature rises in the morning.

* The "Pallium" of Poëy.

The *stratus* is generally a fine weather cloud appearing during the nights and mornings of the brightest days. At times it overspreads the whole sky in the form of a low, gloomy, foggy canopy, the atmosphere at the same time being more or less foggy under it. All low detached clouds, which look like a piece of lifted fog, and are not in any way consolidated into a definite form, are *strati*, and may be called "detached" *stratus*. Lower clouds.

Figs. 5 and 6. **Cumulus** (Cum.). "Convex or conical heaps "increasing upward from a horizontal base."

This class of clouds comprises all those of the lower stratum which have a globular or rounded form, from the small white cloud represented in Fig. 5, to the heavy mass represented in Fig. 6, which is almost a *cumulo-stratus*. The *cumulus* sometimes takes a cylindrical shape, forming itself into long horizontal rolls, between which gleams of light are seen, but which are often so closely packed as to hide the blue sky. These are called by us *Roll-cumulus* (*Roll-c.*). *See* Fig. 5.*

Fig. 7. **Cumulo-stratus** (Cum.-s.). "The 'cirro-stratus' "blended with the 'cumulus,' and either appearing intermixed "with the heaps of the latter, *or superadding a wide-spread struc-* "*ture to its base.*"

This is the *cumulus* as it were changing into a *nimbus*. It is dark and flat at its base, and is traversed by horizontal lines of dark cloud.

Fig. 8. **Nimbus** (Nim.). "The rain cloud. A cloud or system "of clouds from which rain is falling. It is a horizontal sheet "above which the 'cirrus' spreads while the 'cumulus' enters it "laterally and from beneath."

This is a rain-cloud. Whilst on the horizon, or as it advances towards the observer, its front frequently presents a marked outline like that of a very heavy *cumulo-stratus* with rain falling from it, and with some *cirrus* above, so that Howard has called it the *cumulo-cirro-stratus*. When it has overspread the whole sky, it is usually so mixed up with or concealed by the falling rain that it generally assumes a uniform dark appearance.

Fig. 8 represents a *Nimbus* before it has overspread the sky; there are also smaller clouds of the same kind which only produce a passing shower. They are easily distinguished by the fact that rain or snow, &c. is falling from them.

Inasmuch, however, as rain, &c. may fall from clouds of various shapes, anything peculiar in the form, height, &c. of the *nimbus* should be mentioned in the "Remarks."

Scud is a term used to indicate loosely formed, detached clouds drifting rapidly before the wind. These may be either at a high or low level; in the former case they probably belong to the *cirro-stratus* or *cirro-cumulus*, in the latter to *stratus*, but the word scud simply implies that they are fragments of cloud in rapid motion.

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* This variety of *cumulus* is an addition to Howard's nomenclature. It has been inserted owing to the frequency of this appearance at sea. It is unnecessary to observe that the effect is simply one of perspective.

Entry of clouds.

It is believed that the foregoing description is sufficient to explain the ordinary forms of clouds, but the appearances are much intermixed. Thus, before rain we often see a dirty background of *cirro-stratus*, over which black patches of *cirro-cumulus* are travelling. Such combinations, when seen, should be carefully noted.

The direction *from* which all clouds, especially upper clouds, come is very important, and should be recorded, whether they are moving with the wind or not. The relative motion of some clouds past others, or past any moveable object, is so deceptive that it should never be recorded. If the upper clouds move quickly, a remark should be made to that effect.

It is particularly requested that the contractions *Cir.*, *Cir.-c.*, *Cir.-s.*, *Str.*, *Cum.*, *Cum.-s.*, *Nim.*, given on the plates, be used in the entries, as any other contractions are likely to mislead.

Amount of loud.

Amount of Cloud.—The scale for the amount of cloud is that of 0 "Blue Sky," 10 "Entirely overcast."

The following are the resolutions as regards Clouds adopted at Vienna:—

1. "Entries as to the extension of clouds on the visible sky according to the scale 0–10 are to be made without reference to the thickness of the cloud. The latter is to be indicated by an exponent applied to the figure for the Amount of Cloud (0 slight, 2 great).

2. "As to the Forms of Cloud, or rather classes of cloud, the matters most urgently desired are more thorough observations and more accurate drawings, which will correspond to the variety of clouds which are in reality observed, as none of the systems which have as yet been proposed, *e.g.*, that of Poëy, are of such a nature that they can at once be recommended for general adoption.

3. "For the present it is recommended to add to Howard's designations, and their combinations, epithets as characteristic as possible, according to the choice of the individual observer, in order to express the actual appearance as clearly as possible.

4. "In order to facilitate a correct understanding and designation of the clouds, it is recommended:—

(*a*.) "That central offices should prepare, as completely as possible, lists and characteristics of the forms of cloud which occur in their districts.

(*b*.) "That on the part of the Congress the preparation of sketches of the principal Forms of Cloud be set on foot, which should be added to the Instructions for the Observers.

(*c*.) "That the study of the connexion between the form, constitution, and origin of the clouds be undertaken and supported, special attention being paid to the circumstance that one and the same mass of cloud presents a different appearance when seen from different sides or under different angles."

WEATHER.

Under the head of Weather Observations are classified the various appearances which for the most part indicate modifications in the condition of the aqueous vapour in the atmosphere, and which are therefore known in some countries under the generic term of "Hydrometeors." Weather observations.

In this country a system of notation devised by Admiral Beaufort has been in use for many years, but as these phenomena must be noted by each observer in the ordinary language of his country, the Vienna Congress decided that it was advisable to employ for the recording of such observations, symbols, which should be independent of any language, inasmuch as if, as in the Beaufort notation for weather, we, for our own convenience, employ for the most part the initial letters of the English names of the phenomena, we should find great difficulty in recognising the same phenomena when described, *e.g.*, in Russian.

These symbols have been introduced into the form given in App. II. because it is advisable to use in the original schedules of observation the same symbols as are employed in the printed tables, at least for entry in the "Remarks" column.

These symbols, which were adopted at Vienna, are evidently better suited to continental climates than to those of these islands. However, before dealing with them, we shall first give the Beaufort notation, with the corresponding symbols, wherever such exist, and then a list of the symbols which are not represented in the Beaufort notation.

Beaufort Notation with corresponding symbols.

b = blue sky: whether with clear or hazy atmosphere.

c = cloudy, but detached opening clouds.

d = drizzling rain.

f = foggy, ≋

g = dark gloomy weather.

h = hail, ▲

l = lightning, ↯

m = misty hazy atmosphere, ≋ or ∞

o = overcast, the whole sky being covered with an impervious cloud.

p = passing temporary showers.

q = squally.

r = rain, continued rain, ●

s = snow, ✱

t = thunder.

Weather observations

u = "ugly," threatening appearance of the weather.

v = "visibility" of distant objects, whether the sky be cloudy or not.

w = dew,* ⏝

In Beaufort's system, a bar or a dot under a letter denoted intensity.

Symbols not included in the Beaufort Notation.

Thunderstorm - -		Strong Wind - -	
Soft Hail ("Graupel")†	△	Solar Corona - -	⊕
Hoar Frost - -	⊔	„ Halo - -	○
Silver-thaw ("Rauh-frost"† "Duft") - -	V	Lunar Corona - -	
		„ Halo - - -	
Glazed Frost ("Glatteis")†	⁓	Rainbow - - -	⌒
Snow Drift - -		Aurora - - -	
Ice Crystals - -	→	Dust-haze ("Höhen-rauch")†	∞

In these symbols intensity is to be indicated by the exponents 0 and 2 attached to the symbols, thus,

$\ast^0$ means slight snow, $\ast^2$ heavy snow.

We shall take these phenomena in order as they appear above, noting only those which call for remark.

The first that calls for notice is *Fog*. This is only to be entered when the observer is entirely surrounded by it. It will be seen that the same symbol is used for Fog and Mist.

Hail.—The symbol is a shaded triangle. It is to be entered whenever the stones are hard, no matter what their size may be. In this it seems advisable to differ from the practice recommended at Vienna—which is to enter "Hail" only when the stones are large enough to do damage to agricultural products—inasmuch as Hail Insurance is not so common in these islands as on the continent.

Lightning.—The symbol represents a flash of forked lightning. It is to be employed for sheet lightning, as well as for other forms. If thunder is heard with the lightning, the symbol for thunderstorm is to be employed.

Mist, Haze.—The symbol for Mist is the same as for Fog. For Haze, that for "Dust haze" should be employed.

It may here be remarked that it seems a decided defect in the Beaufort Notation to designate by the same initial letter two such different phenomena as "mist" and "haze."

Rain.—The symbol is a black circle. It seems hardly necessary to employ this symbol in these islands, owing to the comparative

* In the original notation given by Admiral Beaufort, the letter "w" indicated "wet, dew," but it has been found that "wet" has been used to indicate *wet weather* instead of a deposition of moisture from a fog.

† German expressions.

rarity of either Snow or Hail, so that any water measured in the rain gauge may be set down as Rain unless the symbol for either of the other forms of precipitation is employed. Weather observations.

Snow.—The symbol is a six-pointed star, a common form of snow crystals. Water crystallizes in what is termed the hexagonal system, and snow flakes when examined show a most exquisite geometrical structure, the separate spiculæ being arranged so as to intersect each other at angles of 60° or 120°.

No symbol is given for "Sleet," mixed snow and rain, in fact this seems to be a phenomenon specially characteristic of northern and insular climates. It is recognized in Norway and Denmark under the name of "*Slud.*" In Germany under that of "*Schlacken.*" The French term "*Grésil,*" which is usually considered equivalent to "Sleet," really indicates "Soft Hail."

Thunder.—No symbol is given for this, as it is considered that the lightning which accompanied it must have been within the range of vision of the observer who heard the thunder, although unnoticed by him, so that accordingly Thunder is always to be entered as Thunderstorm.

Dew.—This is to be noted, the symbol being a representation of a drop of dew.

Thunderstorm.—The symbol is a **T**, combined with the symbol for lightning.

In entering in the register the number of thunderstorms in a month, the days when Sheet Lightning only is observed are to be noted specially.

The direction of motion of thunderstorms should be carefully noted and entered in the "Remarks" column.

Soft Hail, "Graupel." (*Grésil* in French.)—This is a kind of hail very common on the continent, and frequently seen in these islands in cold weather during spring. The stones are small and soft, like little snow pellets, without any crystalline structure.

The symbol is a triangle unshaded.

Silver Thaw is the phenomenon of a large quantity of frozen moisture on trees when the weather suddenly becomes warm after great cold. This occasionally takes place to such an extent that branches are broken off the trees.

Glazed Frost.—This is the phenomenon of a frost setting in after a partial thaw, when the ground and most objects are covered with ice.

Snow Drift.—This phenomenon hardly requires a symbol.

Ice Crystals.—These occasionally fall in winter. They are distinguished from hail by their shape and size. The symbol is an arrow unfeathered.

Strong Wind.—The symbol is that employed by the Meteorological Office in its working Charts. It is convenient to make the number of the feathers indicate the degrees of Beaufort scale.

Weather observations.
Optical phenomena.

Coronæ and Halos are circles which appear round the sun and moon.

Coronæ are small circles exhibiting the prismatic colours, the red being outside, the violet inside; "when two or more are seen "at once, the diameter of the second is double that of the first, of "the third, triple. But the diameter of the interior corona (the "unit of the scale) is not always the same, varying from 2° to 4°."* They arise from the interference of rays passing through a mass of minute globules of water, and accordingly they are seen whenever light clouds pass between us and the moon, and their appearance is so common as scarcely to call for remark. "The reason why "coronæ are seldom seen round the sun, is the dazzling brightness "of that luminary. If its light be enfeebled by reflection in water "or by a coloured glass they are often visible."

Halos.—"These are large circles of definite and constant "diameters, one of 45°, the other of 92°, and which are seldom "both seen together. The colours are very feeble, especially of "the larger, which is usually almost or quite white." The larger is very uncommon. Where they exhibit prismatic colours which is rarely the case, the red is inside. They arise from the existence of minute prisms of ice in the atmosphere, and consist of refracted light.

Sometimes the halo is intensified into two bright spots, one on each side of the central luminary. These are called *Parhelia* or *Paraselenæ* (mock suns or mock moons).

At times the phenomena are even more complicated, and other circles, arcs, and lines are observed, usually intersecting the primary halo symmetrically. At the intersections these multiple images appear. These lines and arcs probably form parts of circles of 45°, 90°, and 180° diameter.

These appearances are exceedingly rare except in high latitudes, and the evidence of observers who have been so fortunate as to see them is somewhat conflicting, so that the explanation of the phenomena is rendered more difficult.

An observer, therefore, should never fail in such cases to draw carefully what he sees *at the time.*

Rainbow.—It seems unnecessary to give a symbol for a phenomenon of such common occurrence and so transient.

Aurora.—When the aurora is fully developed it consists of a bright arch, usually appearing in the north, with streamers emanating from it, which are parallel to the dipping needle. Under the arch the dark sky is seen which is sometimes called the dark segment of the aurora. The arch is somewhat of the nature of a sheet or curtain of light, and it moves from the "magnetic" northern horizon towards the south. At times a succession of arches are seen, as many as nine having been counted at one time by an observer in north of Norway.

* The quotations are from Herschel's Meteorology.

The streamers flash in rapid pulsations, and sometimes extend beyond the Zenith, when they form a closed curve or canopy of light, around a point in the heavens indicated by the direction of the dipping needle, which is therefore situated to the south of the Zenith. This appearance is termed the "corona" of the aurora.

Weather observations.

The colour is usually white, but occasionally red, green, and other colours are noticed.

A very interesting paper by the Rev. Jas. Farquharson on auroral observations in these islands will be found in the Philosophical Transactions, 1829, p. 103.

The symbol is an arc and chord with three rays. In case of specially fine auroral manifestations the observer is requested to send up a fuller notice, *e.g.*, in the space at the foot of the form or on its back.

Dust-Haze, "Höhenrauch."—This is a peculiar obscuration of the atmosphere which sometimes appears in summer. It is far more common on the Continent than with us. Its origin is not quite understood. At times it has been traced to extensive fires on the moors or in the forests of Northern Europe.

HOURS OF OBSERVATION.

Hours of observation.

There is hardly any point which is more difficult to settle than that of the most suitable hours for meteorological observations, inasmuch as those which will give good results in one climate, will be ill adapted to meet the requirements of another. In all cases, it will be remembered, it is temperature to which the observations in the first instance refer.

The mean temperature which is generally assumed as correct for a day is that of the 24 hourly observations, and continuous records are not usually tabulated to greater minuteness than that indicated.* Such frequent observations however entail an amount of labour which cannot be attempted except at a first class Observatory. Speaking generally, two observations a day are the least number which can be recognised as sufficient for a station of the second order, and it is desirable, if possible, to have three observations or more, at regular intervals, during the 24 hours. It is, however, very difficult to ensure the regularity of night observations, and on the whole it has been decided by the Vienna Congress to consider the following combinations of hours (local time) as admissible.

h.	h.	h.	h.	h.	h.		h.	h.	
6 AM	2 PM	10 PM	8 AM	2 PM	8 PM	with minimum temperature.	8 AM	8 PM	with maximum and minimum temperature.
7 ,,	2 ,,	10 ,,	9 ,,	3 ,,	9 ,,		9 ,,	9 ,,	
7 ,,	1 ,,	9 ,,	10 ,,	4 ,,	10 ,,		10 ,,	10 ,,	
7 ,,	2 ,,	9 ,,							

Calculation of means.

The method of treating most of these combinations so as to give the daily mean, and the corrections to be applied to such daily mean for some of the principal observatories, in order to obtain the true daily mean, will be found in the best text books of meteorology.

In the Phil. Trans. for 1848, Mr. Glaisher gives corrections for daily range for Greenwich, and in the Mémoires de l'Académie Royale de Belgique, vol. xxxvi., M. Ernest Quetelet gives a very complete table of the corrections for various combinations of hours for Brussels. All such tables, are however, in the first instance of local value, and the greatest caution is necessary in applying the results to observations taken at other stations and possibly under very different circumstances.

The combination of 9 a.m. and 9 p.m. is that selected for the volunteer observers in the United Kingdom.

The means of these observations do not differ much from the true daily mean.

In connection with the question of the determination of a correct mean for the 24 hours from any combination of a less number of hours, it may be remarked that a common method of obtaining a

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* At the observatory of Helsingfors the observations were recorded at intervals of twenty minutes for the space of nearly nine years!

very nearly accurate mean for the day is to take the average of the maximum and minimum readings for the day, but the resulting value is slightly too high.

It is, however, obvious that for such a mean to be strictly correct for the 24 hours of the civil day, ending at midnight, the observations of the extreme temperatures should be taken at the expiration of the interval, *i.e.*, at midnight. This is evidently not possible at all stations, and hence a chance of error may arise.

The, hitherto, ordinary practice of reading both instruments at 9 a.m. may occasionally in winter give rise to error as regards an individual day, for at that season the diurnal march of temperature is often masked by the serious contrasts between the temperatures of the winds from the different points of the compass, so that to apply the extreme readings taken at 9 a.m. to ascertain the mean temperature for the day ending at the preceding midnight, must occasionally lead to error.

Notwithstanding this objection, the mean of the maximum and minimum temperatures remains the simplest method of ascertaining the mean temperature, and the liability to error to which allusion has been made has been materially reduced by the practice, which is recommended by the Vienna Congress, of reading the maximum and minimum thermometers at the latest observing hour of the day, so that the observations shall be taken as near midnight as is reasonably possible.

REMARKS TO OBSERVERS.

NOTES ON FILLING UP THE FORM—App. II.

Experience shows that it is necessary, even at the risk of repetition, to say a few words as to the method of observing, and to point out the kind of errors to which observers are most liable in reading their instruments. The necessity for punctuality has been already mentioned.

In the following remarks a great many things will be included to which some observers will not find leisure to attend. But others may have more time; and in all cases it is advisable that observers should be on the alert as to the special points which are of most importance to be noted.

Entry of observations.

1. While too much time should never be spent in setting and reading off the instruments, anything like hurry should be still more strongly discouraged.

Let every reading be entered in a "rough book" before leaving the instruments, and examined to see that it is recorded correctly. In filling up the form see that all the necessary figures are written clearly and placed in their proper positions. Never *omit* a figure, not even the last decimal place when it is a cypher. This instruction is necessary because some observers who generally read their barometer to three places of decimals, and their thermometers to tenths, will enter "29·44" instead of "29·440," and 45° instead of 45°·0; then the figures may be placed a little out of position, and in totalling are liable to be included in the wrong column. Let the whole numbers, too, be regularly entered. In filling up the "Weather" and "Remarks" columns avoid large flourishes, in order that the letters and words may be caught by the computer without difficulty.

Reading the barometer.

2. *With regard to the Barometer.*—It is necessary that the height of the cistern of the instrument (not merely of the ground on which the house containing the instrument stands) above the mean sea level should be accurately known. In applying the corrections for altitude, due allowance must be made for the temperature of the outside air at the time of observation, and also for the approximate *sea level* pressure at the same time, as variations in either of these particulars make *material* alterations as to the correction necessary whenever the altitude exceeds about 30 feet.

Supposing, however, that the correction table is properly prepared, and the barometer truly hung, the first thing to be done in taking an observation is to read and enter the indication of the attached thermometer.

Should the barometer be on Fortin's principle, let the utmost care be exercised that the mercury in the cistern be adjusted so as

to touch, but *only just touch*, the zero point. Great care is necessary in order to do this well. Equal pains must be taken to ensure that the plane of lower edges of the back and front of the vernier may form *exactly* a tangent to the convex surface of the column.

Then in reading off, the principal errors to guard against are those of five tenths or five hundredths of an inch—so reading, say, 29·345 for 29·845 or 29·284 for 29·234, or *vice versâ*. See also that the tenths are properly counted; ·7 is often read as ·8.

3. *In reading thermometers,* do so as speedily as may be consistent with accuracy, and without breathing on the bulbs. Let both the maximum and minimum be read, and the reading entered and checked before the instruments are touched for setting. See that the corrected minimum reading is not higher, nor the maximum lower, than any of the dry bulb readings taken during the day. Should such a discrepancy be discovered, spare no pains to ascertain where the error has been made, and if possible *rectify* it, but do not make any forced entries in such cases, so that things may appear right which are really wrong or doubtful. It will be far better to call attention, to the discrepancy by a note, than in any way to "cook" or tamper with a reading. In setting the maximum and minimum thermometers, see that the work is done completely, so that they indicate the temperature at the time of setting. The maximum shade temperature ordinarily occurs early in the afternoon, and the minimum shortly before sunrise. Whenever it is noticed that these readings occur at abnormal hours, add a note to that effect in the "remarks" for the day. See that the wet bulb is moist and clean; and should the observer be reading to whole degrees only (*a very rough and an inadmissible practice for the higher class of stations*) take care that the difference between the dry and wet bulb readings is given to the nearest degree. The importance of this is evident on very little reflection. Reading the thermometer.

Thus 47°·4 (Dry.) 45°·6 (Wet.) should not be entered by anyone reading to whole degrees, as 47° | 46°, but as 47° | 45°, for there is 1°·8 difference between the two, which is much nearer to 2° than 1°.

Should the water in the cistern of the wet bulb need replenishing, let it be done immediately *after* an observation has been made, and while doing so let the muslin, worsted, and bulb be well washed. (It is well to keep the water which is collected in the rain gauge for this purpose, as by that means the incrustation of carbonate of lime, &c., on the wet bulb is avoided, and the muslin, &c., need to be changed less frequently.)

4. *In observing the wind,* take care that no mere local eddy is entered instead of the true current prevailing over the station; and should any *marked* change take place during the interval between the observations—such as a sudden gale or severe squall—note it carefully in the "Remarks" column. Should the direction have changed much, say from S.W. to N.E., note in which way the shift took place. Both the direction and force may be best Observations of wind.

estimated by noting the drift of smoke from tall chimneys which are *near* the observer, or from chimneys in clear spaces. The indications of anemometers placed on ordinary dwelling-houses, or in any position not *carefully* selected, should be distrusted *very* much.

Entry of clouds.

5. *Clouds.*—Note the most prevalent forms. Should any particular form be massed in one part of the heavens more than in another; or should different strata be moving in different directions, or at *very* different velocities, let such facts be entered in the "Remarks" column. When clouds are increasing, try to discover whether it is merely that they are rising from below the horizon, or that they are being formed within the sphere of observation. If the latter be the case, add a note to that effect. In the same manner, should clouds be disappearing by evaporation, let this be carefully noted. It will sometimes happen that when *cumuli* are disappearing by evaporation they become so thin that they appear almost like low *cirri;* care will therefore be necessary not to enter the wrong name. Two or more strata of clouds may be recorded by being entered with a line or lines drawn between their names, thus:—

cir	N.W.
Thin cum	S.W.
Heavy cum	S.W. fast.

where three strata are shown, together with the directions whence they are moving.

Entry of weather.

6. *Weather.*—The letters of the Beaufort notation are to be used in the Weather columns, the symbols in the Remarks column. There are three of the letters of the Beaufort notation which refer to the amount of cloud, "b." "c." and "o."; it is obvious that for any observation at a definite hour only one of these letters is admissible, thus, the weather cannot possibly be "b" and "c" at the same time. In the columns for the "Weather since last observation," it may be necessary to enter the weather for two or more intervals. When this is the case, each period should be separated by a comma; thus, "b,c,op,g," will show that the weather after being fine became overcast and showery, and afterwards gloomy, without rain. As the letter "p." when used alone, means "passing showers of rain," the letters "pr" should not be used together to signify showers of rain; but "ps" or "ph" may be used for "showers of snow" or "hail", as the case may be, and "phr" will mean "showers of hail and rain," &c. In noting Halos give the estimated length of their radius in degrees, and say whether the ring or rings have prismatic colours. Let Auroræ be carefully noted, both as to the direction in which they are seen, the altitude to which they extend, duration, colours, and brilliancy.

Entry of rain.

7. *Rainfall.*—Supposing the gauge to be properly fixed and exposed, let the water be poured steadily into the measuring glass, which must be standing on a perfectly level surface, so that none may be spilt, and enter the reading in the "rough

book," before the water is poured away. In entering the Hours of Rain, let only that period be recorded during which rain was actually falling, to the best of the observer's knowledge. When the rainfall has been much heavier during one part of a day than at others, let a note be added to that effect in the "Remarks" column.

It is not pretended that every remark necessary has been made above; but sufficient is stated to show the nature of the matters to which the greatest attention should be paid; and it is, moreover, believed that observers, by careful attention to them, will catch some idea of the spirit of watchfulness for changes in the weather which should be manifested at a good station.

In App. III. will be found the circular letter of questions addressed to all observers at stations of the second order, in connection with the Meteorological Office.

NOTES ON THE CALCULATION OF MEAN RESULTS.

When summing the various columns in order to obtain the mean values, a very considerable saving of time can be effected by the use of constants. Let us suppose, for example, in the case of a column of barometrical observations for a month of 31 days, that it is evident by a mere glance at the individual observations that the mean will be 29 inches and a decimal: when summing this column, it is preferable not to sum the whole numbers of the inches, but to reject 29 inches as a constant, and merely sum the decimal parts. Let us suppose that the sum of the *decimal figures* in this column is 18·738, and that in the whole numbers of inches, 30 occurs five times, and 28 once, so that adding 1 for each 30, (its excess on the constant 29), and taking off 1 for 28, (the amount of its defect on 29), we get $18 + 5 - 1 = 22$. The sum, obtained by thus rejecting 29 inches, being accordingly 22·738, this sum is 29·000 inches × 31 (the number of observations), or 899·000 less than that obtained by simple summation; of course, when the sum is divided by the number of observations, the constant (29 inches) will be prefixed for the mean. Use of constants.

Constants should also be used when summing the columns for the dry and wet thermometers Vapour Tension and the maximum and minimum temperatures.

Care being necessary that the values thus thrown out should be correctly prefixed to the mean result, it is a good plan to enter the constant used in a bracket (29·0) at the foot of its proper column.

This use of constants, although in no way affecting the results obtained, is strongly recommended as a useful course to be adopted, and it will be seen that they can be employed very extensively in work of this description.

APPENDIX I.

EXPLANATION OF THE TABLES.

TABLE I. contains the correction to be applied to the readings of barometers mounted in *brass* frames, in order to reduce them to the normal temperature, 32°. It has been computed from the following formula given by Schumacher—

$$\text{Correction} = -h\,\frac{m\,(t-32) - s\,(t-62)}{1 + m\,(t-32)}$$

in which

h = reading of the barometer,
t = temperature of attached thermometer,
m = expansion of mercury for 1° F., taken as ·0001001 of its length at 32°,
s = expansion of the substance of which the scale is made; for brass s is taken as ·00001041 of its length (h) at the standard temperature for the scale, viz., 62° F.

TABLE II. is for reducing to the sea-level observations of the barometer made at any height not exceeding 1,500 feet. It is given for two pressures at the lower station, namely, 30 and 27 inches. For intermediate pressures, the correction may be obtained by proportional parts.

For heights exceeding those given in the Table, the value at the sea-level, of a barometer reading at a station, the height of which is known, may be calculated from the following formula :—

$$\text{Log}\,\frac{h}{h'} = f \div \left\{ 60159\left(1 + \frac{t+t'-64}{900}\right)\left(1 + \cdot 00268 \cos 2\,l\right)\left(1 + \frac{f + 52251}{20886861}\right) \right\}$$

From a table of common logarithms, the natural number corresponding to log $\frac{h}{h'}$ is found; or, $\frac{h}{h'} = n$,

And $h = n\,h'$.

In this formula—

h and h' = barometer reduced to 32° F. at the lower and upper stations respectively,
t and t' = the temperature of the air at the respective stations,
f = elevation of upper station in feet,
l = latitude of the place.

The above formula is merely an inversion of the well-known formula given by Laplace in his *Mécanique Céleste,* for finding the difference of elevation between any two places by means of the barometer, which, adapted to Fahrenheit's thermometer and English feet and inches, is,—

$$f = 60159 \log \frac{h}{h'}\left(1 + \frac{t+t'-64}{900}\right)\left(1 + \cdot 00268 \cos 2\,l\right)\left(1 + \frac{f + 52251}{20886861} + \frac{x}{10443430}\right)$$

In this formula f is the difference of elevation between the two stations, and x is the height of the lower station above the sea-level.

In the last factor an approximate value must be used for f.

TABLE III. is for converting the reading from barometers having millimetre scales, into English inches.

TABLE IV. is for converting the readings from barometers having inch scales into millimetres.

They are computed from Captain Kater's determination of the length of the French metre in English inches (*see* Phil. Trans. for 1818, p. 109), viz., 1 metre at 32° F. = 39·37079 inches at 62° F.

Before using the Tables, the barometer observations must be reduced to the normal temperature of 32° F., as per Table I., if the scale be English; but if

it be a French scale, the French Table for the purpose must be employed, for which see Guyot's "Tables—Meteorological and Physical," published by the Smithsonian Institution.

TABLE V. is for converting the readings of barometers having old French scales (Paris Lines) into English inches.

The standard temperature for Paris lines in 61°·25 F., and for English inches 62° F. The Table supposes the barometric height to be reduced to 32°, and expressed in Paris lines at the temperature 61°·25, and gives the equivalents in inches at 62°. If used reversely the barometric height in inches should be reduced to 32° by Table I., before the corresponding value in lines is sought. As, however, the standard temperatures for the scales are so nearly alike, the consideration of their temperature may be practically disregarded.

TABLE VI. is for converting the readings of thermometers having Centigrade scales into Fahrenheit.

TABLE VII. is for converting the readings of thermometers having Fahrenheit scales into Centigrade.

TABLE VIII. is for converting the readings of thermometers having Reaumur scales into Fahrenheit.

TABLE IX. for facilitating the conversion of Rainfall measurements in millimeters (1–240) into inches, is based upon the value of the metre in inches at equal temperatures in ordinary air, namely 1 metre = 39·38203 inches. (*See* Appendix to the Fifth Report of Standards Commission, p. 186.)

TABLE X. for facilitating the conversion of Rainfall measurements in inches (0·1–20·9) into millimetres, is based upon the value of the yard in relation to the metre at equal temperatures in ordinary air, namely 1 yard = 0·91412 metre. (*See* Appendix to the Fifth Report of Standards Commission, p. 186.)

TABLE I.—Correction to be applied to Barometers with *Brass Scales*, extending from the Cistern to the top of the Mercurial Column, to reduce the observation to 32° Fahrenheit.

Temp.	INCHES.															Temp.
	24·0	24·5	25·0	25·5	26·0	26·5	27·0	27·5	28·0	28·5	29·0	29·5	30·0	30·5	31·0	
	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
0°	·061	·063	·064	·065	·067	·068	·069	·071	·072	·073	·074	·076	·077	·078	·080	0°
1	·059	·061	·062	·063	·064	·065	·067	·068	·069	·071	·072	·073	·074	·076	·077	1
2	·057	·058	·060	·061	·062	·063	·064	·066	·067	·068	·069	·070	·072	·073	·074	2
3	·055	·056	·057	·059	·060	·061	·062	·063	·064	·065	·067	·068	·069	·070	·071	3
4	·053	·054	·055	·056	·057	·058	·059	·061	·062	·063	·064	·065	·066	·067	·068	4
5	·051	·052	.053	·054	·055	·056	·057	·058	·059	·060	·061	·062	·063	·065	·066	5
6	·049	·050	·051	·052	·053	·054	·055	·056	·057	·058	·059	·060	·061	·062	·063	6
7	·046	·047	·048	·049	·050	·051	·052	·053	·054	·055	·056	·057	·058	·059	·060	7
8	·044	·045	·046	·047	·048	·049	·050	·051	·052	·053	·054	·054	·055	·056	·057	8
9	·042	·043	·044	·045	·046	·046	·047	·048	·049	·050	·051	·052	·053	·054	·054	9
10	·040	·041	·042	·042	·043	·044	·045	·046	·047	·047	·048	·049	·050	·051	·052	10
11	·038	·039	·039	·040	·041	·042	·042	·043	·044	·045	·046	·046	·047	·048	·049	11
12	·036	·036	·037	·038	·039	·039	·040	·041	·042	·042	·043	·044	·045	·045	·046	12
13	·033	·034	·035	·036	·036	·037	·038	·038	·039	·040	·040	·041	·042	·043	·043	13
14	·031	·032	·033	·033	·034	·035	·035	·036	·037	·037	·038	·038	·039	·040	·040	14
15	·029	·030	·030	·031	·032	·032	·033	·033	·034	·035	·035	·036	·036	·037	·038	15
16	·027	·028	·028	·029	·029	·030	·030	·031	·032	·032	·033	·033	·034	·034	·035	16
17	·025	·025	·026	·026	·027	·027	·028	·028	·029	·030	·030	·031	·031	·032	·032	17
18	·023	·023	·024	·024	·025	·025	·025	·026	·026	·027	·027	·028	·028	·029	·029	18
19	·021	·021	·021	·022	·022	·023	·023	·024	·024	·024	·025	·025	·026	·026	·027	19
20	·018	·019	·019	·020	·020	·020	·021	·021	·021	·022	·022	·023	·023	·023	·024	20
21	·016	·017	·017	·017	·018	·018	·018	·019	·019	·019	·020	·020	·020	·021	·021	21
22	·014	·014	·015	·015	·015	·016	·016	·016	·016	·017	·017	·017	·018	·018	·018	22
23	·012	·012	·012	·013	·013	·013	·013	·014	·014	·014	·014	·015	·015	·015	·015	23
24	·010	·010	·010	·010	·011	·011	·011	·011	·011	·012	·012	·012	·012	·012	·013	24
25	·008	·008	·008	·008	·008	·008	·009	·009	·009	·009	·009	·009	·009	·010	·010	25
26	·005	·006	·006	·006	·006	·006	·006	·006	·006	·006	·007	·007	·007	·007	·007	26
27	·003	·003	·003	·003	·004	·004	·004	·004	·004	·004	·004	·004	·004	·004	·004	27
28	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	28
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
29	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	·001	29
30	·003	·003	·003	·004	·004	·004	·004	·004	·004	·004	·004	·004	·004	·004	·004	30
31	·005	·006	·006	·006	·006	·006	·006	·006	·006	·006	·007	·007	·007	·007	·007	31
32	·008	·008	·008	·008	·008	·008	·008	·009	·009	·009	·009	·009	·009	·010	·010	32
33	·010	·010	·010	·010	·011	·011	·011	·011	·011	·012	·012	·012	·012	·012	·012	33
34	·012	·012	·012	·013	·013	·013	·013	·014	·014	·014	·014	·015	·015	·015	·015	34
35	·014	·014	·015	·015	·015	·015	·016	·016	·016	·017	·017	·017	·018	·018	·018	35
36	·016	·017	·017	·017	·017	·018	·018	·019	·019	·019	·020	·020	·020	·021	·021	36
37	·018	·019	·019	·019	·020	·020	·021	·021	·021	·022	·022	·022	·023	·023	·024	37
38	·020	·021	·021	·022	·022	·023	·023	·023	·024	·024	·025	·025	·026	·026	·026	38
39	·023	·023	·024	·024	·024	·025	·025	·026	·026	·027	·027	·028	·028	·029	·029	39
40	·025	·025	·026	·026	·027	·027	·028	·028	·029	·029	·030	·030	·031	·031	·032	40
41	·027	·027	·028	·029	·029	·030	·030	·031	·031	·032	·033	·033	·034	·034	·035	41
42	·029	·030	·030	·031	·031	·032	·033	·033	·034	·034	·035	·036	·036	·037	·037	42
43	·031	·032	·032	·033	·034	·034	·035	·036	·036	·037	·038	·038	·039	·040	·040	43
44	·033	·034	·035	·035	·036	·037	·037	·038	·039	·040	·040	·041	·042	·042	·043	44
45	·035	·036	·037	·038	·038	·039	·040	·041	·041	·042	·043	·044	·044	·045	·046	45
46	·038	·038	·039	·040	·041	·042	·042	·043	·044	·045	·045	·046	·047	·048	·049	46
47	·040	·041	·041	·042	·043	·044	·045	·046	·046	·047	·048	·049	·050	.051	·051	47
48	·042	·043	·044	·045	·045	·046	·047	·048	·049	·050	·051	·052	·052	·053	·054	48
49	·044	·045	·046	·047	·048	·049	·050	·050	·051	·052	·053	·054	·055	·056	·057	49
50	·046	·047	·048	·049	·050	·051	·052	·053	·054	·055	·056	·057	·058	·059	·060	50

TABLE I.—*continued.*

Temp.	INCHES.															Temp.
	24·0	24·5	25·0	25·5	26·0	26·5	27·0	27·5	28·0	28·5	29·0	29·5	30·0	30·5	31·0	
51°	·048	·049	·050	·051	·052	·053	·054	·055	·056	·057	·058	·059	·060	·061	·062	51°
52	·050	·052	·053	·054	·055	·056	·057	·058	·059	·060	·061	·062	·063	·064	·065	52
53	·053	·054	·055	·056	·057	·058	·059	·060	·061	·063	·064	·065	·066	·067	·068	53
54	·055	·056	·057	·058	·059	·060	·062	·063	·064	·065	·066	·067	·068	·070	·071	54
55	·057	·058	·059	·060	·062	·063	·064	·065	·066	·068	·069	·070	·071	·072	·073	55
56	·059	·060	·061	·063	·064	·065	·066	·068	·069	·070	·071	·073	·074	·075	·076	56
57	·061	·062	·064	·065	·066	·068	·069	·070	·071	·073	·074	·075	·076	·078	·079	57
58	·063	·065	·066	·067	·069	·070	·071	·073	·074	·075	·077	·078	·079	·081	·082	58
59	·065	·067	·068	·070	·071	·072	·074	·075	·076	·078	·079	·080	·082	·083	·085	59
60	·068	·069	·070	·072	·073	·075	·076	·077	·079	·080	·082	·083	·085	·086	·087	60
61	·070	·071	·073	·074	·075	·077	·078	·080	·081	·083	·084	·086	·087	·089	·090	61
62	·072	·073	·075	·076	·078	·079	·081	·082	·084	·085	·087	·088	·090	·091	·093	62
63	·074	·076	·077	·079	·080	·082	·083	·085	·086	·088	·089	·091	·093	·094	·096	63
64	·076	·078	·079	·081	·082	·084	·086	·087	·089	·090	·092	·094	·095	·097	·098	64
65	·078	·080	·082	·083	·085	·086	·088	·090	·091	·093	·095	·096	·098	·100	·101	65
66	·080	·082	·084	·085	·087	·089	·090	·092	·094	·096	·097	·099	·101	·102	·104	66
67	·083	·084	·086	·088	·089	·091	·093	·095	·096	·098	·100	·102	·103	·105	·107	67
68	·085	·086	·088	·090	·092	·094	·095	·097	·099	·101	·102	·104	·106	·108	·109	68
69	·087	·089	·090	·092	·094	·096	·098	·100	·101	·103	·105	·107	·109	·110	·112	69
70	·089	·091	·093	·095	·096	·098	·100	·102	·104	·106	·108	·109	·111	·113	·115	70
71	·091	·093	·095	·097	·099	·101	·102	·104	·106	·108	·110	·112	·114	·116	·118	71
72	·093	·095	·097	·099	·101	·103	·105	·107	·109	·111	·113	·115	·117	·119	·120	72
73	·095	·097	·099	·101	·103	·105	·107	·109	·111	·113	·115	·117	·119	·121	·123	73
74	·097	·099	·102	·104	·106	·108	·110	·112	·114	·116	·118	·120	·122	·124	·126	74
75	·100	·102	·104	·106	·108	·110	·112	·114	·116	·118	·120	·122	·125	·127	·129	75
76	·102	·104	·106	·108	·110	·112	·114	·117	·119	·121	·123	·125	·127	·129	·131	76
77	·104	·106	·108	·110	·112	·115	·117	·119	·121	·123	·126	·128	·130	·132	·134	77
78	·106	·108	·110	·113	·115	·117	·119	·122	·124	·126	·128	·130	·133	·135	·137	78
79	·108	·110	·113	·115	·117	·119	·122	·124	·126	·128	·131	·133	·135	·137	·140	79
80	·110	·113	·115	·117	·119	·122	·124	·126	·129	·131	·133	·136	·138	·140	·143	80
81	·112	·115	·117	·119	·122	·124	·126	·129	·131	·134	·136	·138	·141	·143	·145	81
82	·114	·117	·119	·122	·124	·126	·129	·131	·134	·136	·138	·141	·143	·146	·148	82
83	·117	·119	·121	·124	·126	·129	·131	·134	·136	·139	·141	·143	·146	·148	·151	83
84	·119	·121	·124	·126	·129	·131	·134	·136	·139	·141	·144	·146	·149	·151	·154	84
85	·121	·123	·126	·128	·131	·133	·136	·139	·141	·144	·146	·149	·151	·154	·156	85
86	·123	·126	·128	·131	·133	·136	·138	·141	·144	·146	·149	·151	·154	·156	·159	86
87	·125	·128	·130	·133	·136	·138	·141	·143	·146	·149	·151	·154	·157	·159	·162	87
88	·127	·130	·133	·135	·138	·141	·143	·146	·149	·151	·154	·157	·159	·162	·165	88
89	·129	·132	·135	·137	·140	·143	·146	·148	·151	·154	·156	·159	·162	·165	·167	89
90	·131	·134	·137	·140	·142	·145	·148	·151	·153	·156	·159	·162	·164	·167	·170	90
91	·134	·136	·139	·142	·145	·148	·150	·153	·156	·159	·162	·165	·167	·170	·173	91
92	·136	·139	·141	·144	·147	·150	·153	·156	·158	·161	·164	·167	·170	·172	·175	92
93	·138	·141	·144	·147	·149	·152	·155	·158	·161	·164	·167	·170	·172	·175	·178	93
94	·140	·143	·146	·149	·152	·155	·157	·161	·163	·166	·169	·172	·175	·177	·180	94
95	·142	·145	·148	·151	·154	·157	·160	·163	·166	·169	·172	·175	·178	·180	·185	95
96	·144	·147	·150	·153	·156	·159	·162	·165	·168	·171	·174	·178	·181	·183	·183	96
97	·146	·149	·152	·156	·159	·162	·165	·168	·171	·174	·177	·180	·183	·186	·189	97
98	·148	·152	·155	·158	·161	·164	·167	·170	·173	·176	·179	·183	·186	·188	·191	98
99	·151	·154	·157	·160	·163	·166	·169	·173	·176	·179	·182	·185	·188	·191	·194	99
100	·153	·156	·159	·162	·165	·169	·172	·175	·178	·181	·184	·188	·191	·194	·197	100

TABLE II.

Table for reducing Observations of the Barometer to Sea Level, Correction additive.

(Barometer Reading at Sea Level, 30 inches.)

Height in Feet.	TEMPERATURE OF EXTERNAL AIR—DEGREES FAHRENHEIT.													Height in Feet.
	−20°	−10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	
10	·013	·013	·012	·012	·012	·012	·011	·011	·011	·011	·010	·010	·010	10
20	·026	·025	·025	·024	·023	·023	·023	·022	·022	·021	·021	·020	·020	20
30	·039	·038	·037	·036	·035	·034	·034	·033	·032	·032	·031	·030	·030	30
40	·052	·050	·049	·048	·047	·046	·045	·044	·043	·042	·041	·040	·040	40
50	·065	·063	·061	·060	·059	·058	·056	·055	·054	·053	·052	·051	·050	50
60	·077	·076	·074	·072	·070	·069	·068	·066	·065	·063	·062	·061	·059	60
70	·090	·088	·086	·084	·082	·081	·078	·077	·076	·074	·072	·071	·069	70
80	·103	·101	·098	·096	·094	·092	·090	·088	·086	·084	·082	·081	·079	80
90	·116	·113	·111	·108	·105	·104	·101	·099	·097	·095	·093	·091	·089	90
100	·129	·126	·123	·120	·117	·115	·112	·110	·108	·105	·103	·101	·099	100
110	·142	·139	·135	·132	·129	·126	·123	·121	·119	·116	·113	·111	·109	110
120	·155	·151	·148	·144	·140	·138	·134	·132	·129	·126	·124	·121	·119	120
130	·168	·164	·160	·156	·152	·149	·146	·143	·140	·137	·134	·131	·129	130
140	·181	·176	·172	·168	·164	·161	·157	·154	·151	·147	·144	·141	·139	140
150	·194	·189	·185	·180	·176	·172	·168	·165	·162	·158	·155	·152	·149	150
160	·206	·201	·197	·192	·187	·183	·179	·176	·172	·168	·165	·162	·158	160
170	·219	·214	·209	·204	·199	·195	·190	·187	·183	·179	·175	·172	·168	170
180	·232	·227	·222	·216	·211	·206	·202	·198	·194	·189	·185	·182	·178	180
190	·245	·239	·234	·228	·222	·218	·213	·209	·204	·200	·196	·192	·188	190
200	·258	·252	·246	·240	·234	·229	·224	·220	·215	·210	·206	·202	·198	200
210	·271	·264	·258	·252	·246	·240	·235	·231	·226	·221	·216	·212	·208	210
220	·284	·277	·270	·264	·257	·252	·246	·242	·236	·231	·227	·222	·218	220
230	·296	·289	·283	·276	·269	·263	·257	·253	·247	·242	·237	·232	·228	230
240	·309	·302	·295	·288	·281	·275	·269	·264	·258	·252	·248	·242	·238	240
250	·322	·314	·307	·300	·293	·286	·280	·275	·269	·263	·258	·253	·248	250
260	·335	·327	·319	·311	·304	·297	·291	·285	·279	·273	·268	·263	·257	260
270	·348	·339	·331	·323	·316	·309	·302	·296	·290	·284	·278	·273	·267	270
280	·360	·352	·344	·335	·328	·320	·314	·307	·301	·294	·288	·283	·277	280
290	·373	·364	·356	·347	·339	·332	·325	·318	·311	·305	·299	·293	·287	290
300	·386	·377	·368	·359	·351	·343	·336	·329	·322	·315	·309	·303	·297	300
310	·399	·389	·380	·371	·363	·354	·347	·340	·333	·326	·319	·313	·307	310
320	·412	·402	·392	·383	·374	·366	·358	·351	·343	·336	·329	·323	·317	320
330	·424	·414	·404	·395	·386	·377	·369	·362	·354	·347	·340	·333	·326	330
340	·437	·427	·416	·407	·397	·389	·380	·373	·365	·357	·350	·343	·336	340
350	·450	·439	·429	·419	·409	·400	·392	·384	·376	·368	·360	·353	·346	350
360	·463	·451	·441	·430	·421	·411	·403	·394	·386	·378	·370	·363	·356	360
370	·476	·464	·453	·442	·432	·423	·414	·405	·397	·389	·380	·373	·366	370
380	·488	·476	·465	·454	·444	·434	·425	·416	·408	·399	·391	·383	·375	380
390	·501	·489	·477	·466	·455	·446	·436	·427	·418	·410	·401	·393	·385	390
400	·514	·501	·489	·478	·467	·457	·447	·438	·429	·420	·411	·403	·395	400
410	·527	·513	·501	·490	·479	·468	·458	·449	·440	·430	·421	·413	·405	410
420	·539	·526	·513	·502	·490	·480	·469	·460	·450	·441	·431	·423	·415	420
430	·552	·538	·525	·513	·502	·491	·480	·470	·461	·451	·442	·433	·425	430
440	·565	·551	·537	·525	·513	·502	·491	·481	·471	·462	·452	·443	·434	440
450	·578	·563	·550	·537	·525	·513	·503	·492	·482	·472	·462	·453	·444	450
460	·590	·575	·562	·549	·537	·525	·514	·503	·493	·482	·472	·463	·454	460
470	·603	·588	·574	·561	·548	·536	·525	·514	·503	·493	·482	·473	·464	470
480	·616	·600	·586	·572	·560	·547	·536	·524	·514	·503	·493	·483	·474	480
490	·628	·613	·598	·584	·571	·559	·547	·535	·524	·514	·503	·493	·483	490
500	·641	·625	·610	·596	·583	·570	·558	·546	·535	·524	·513	·503	·493	500

TABLE II.—*continued.*

(Barometer Reading at Sea Level, 27 inches.)

Height in Feet.	−20°	−10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	Height in Feet.
	TEMPERATURE OF EXTERNAL AIR—DEGREES FAHRENHEIT.													
10	·012	·011	·011	·011	·011	·010	·010	·010	·010	·010	·009	·009	·009	10
20	·023	·023	·022	·022	·021	·021	·020	·020	·019	·019	·019	·018	·018	20
30	·035	·034	·033	·032	·032	·031	·030	·030	·029	·028	·028	·027	·027	30
40	·046	·046	·044	·043	·042	·041	·040	·040	·039	·038	·037	·036	·036	40
50	·058	·057	·056	·054	·053	·052	·051	·050	·049	·048	·047	·046	·045	50
60	·070	·068	·067	·065	·064	·062	·061	·059	·058	·057	·056	·055	·053	60
70	·081	·080	·078	·076	·074	·072	·071	·069	·068	·066	·065	·064	·062	70
80	·093	·091	·089	·086	·085	·082	·081	·079	·078	·076	·074	·073	·071	80
90	·104	·103	·100	·097	·095	·093	·091	·089	·087	·085	·084	·082	·080	90
100	·116	·114	·111	·108	·106	·103	·101	·099	·097	·095	·093	·091	·089	100
110	·128	·125	·122	·119	·116	·113	·111	·109	·107	·104	·102	·100	·098	110
120	·139	·137	·133	·130	·127	·124	·121	·119	·116	·114	·112	·109	·107	120
130	·151	·148	·144	·140	·137	·134	·131	·129	·126	·123	·121	·118	·116	130
140	·162	·159	·155	·151	·148	·144	·141	·139	·136	·133	·130	·127	·125	140
150	·174	·170	·166	·162	·158	·155	·152	·149	·146	·142	·139	·136	·134	150
160	·186	·182	·177	·173	·169	·165	·162	·158	·155	·152	·149	·146	·143	160
170	·197	·193	·188	·184	·179	·175	·172	·168	·165	·161	·158	·155	·152	170
180	·209	·204	·199	·194	·190	·185	·182	·178	·175	·171	·167	·164	·161	180
190	·220	·216	·210	·205	·200	·196	·192	·188	·184	·180	·177	·173	·170	190
200	·232	·227	·221	·216	·211	·206	·202	·198	·194	·190	·186	·182	·178	200
210	·244	·238	·232	·227	·221	·216	·212	·208	·204	·199	·195	·191	·187	210
220	·255	·249	·243	·237	·232	·227	·222	·218	·213	·209	·204	·200	·196	220
230	·267	·261	·254	·248	·242	·237	·232	·227	·223	·218	·214	·209	·205	230
240	·278	·272	·265	·259	·253	·247	·242	·237	·232	·228	·223	·218	·214	240
250	·290	·283	·276	·270	·263	·258	·252	·247	·242	·237	·232	·227	·223	250
260	·301	·294	·287	·280	·274	·268	·262	·257	·252	·246	·241	·236	·231	260
270	·313	·305	·298	·291	·284	·278	·272	·267	·261	·256	·250	·245	·240	270
280	·324	·317	·309	·302	·295	·288	·282	·276	·271	·265	·260	·254	·249	280
290	·336	·328	·320	·312	·305	·299	·292	·286	·280	·275	·269	·263	·258	290
300	·347	·339	·331	·323	·316	·309	·302	·296	·290	·284	·278	·272	·267	300
310	·359	·350	·342	·334	·326	·319	·312	·306	·300	·293	·287	·281	·276	310
320	·370	·361	·353	·344	·337	·329	·322	·316	·309	·303	·296	·290	·285	320
330	·382	·373	·364	·355	·347	·340	·332	·325	·319	·312	·306	·299	·294	330
340	·393	·384	·375	·366	·358	·350	·342	·335	·328	·322	·315	·308	·303	340
350	·405	·395	·386	·377	·368	·360	·352	·345	·338	·331	·324	·318	·312	350
360	·416	·406	·396	·387	·378	·370	·362	·355	·348	·340	·333	·327	·320	360
370	·428	·417	·407	·398	·389	·380	·372	·365	·357	·350	·342	·336	·329	370
380	·439	·429	·418	·409	·399	·391	·382	·374	·367	·359	·352	·345	·338	380
390	·451	·440	·429	·419	·410	·401	·392	·384	·376	·369	·361	·354	·347	390
400	·462	·451	·440	·430	·420	·411	·402	·394	·386	·378	·370	·363	·356	400
410	·473	·462	·451	·441	·430	·421	·412	·404	·395	·387	·379	·372	·365	410
420	·485	·473	·462	·451	·441	·431	·422	·413	·405	·397	·388	·381	·374	420
430	·496	·485	·473	·462	·451	·442	·432	·423	·414	·406	·398	·390	·382	430
440	·508	·496	·484	·472	·462	·452	·442	·433	·424	·415	·407	·399	·391	440
450	·519	·507	·495	·483	·472	·462	·452	·442	·433	·424	·416	·408	·400	450
460	·530	·518	·505	·494	·482	·472	·462	·452	·443	·434	·425	·417	·409	460
470	·542	·529	·516	·504	·493	·482	·472	·462	·452	·443	·434	·426	·418	470
480	·553	·541	·527	·515	·503	·493	·482	·472	·462	·452	·444	·435	·426	480
490	·565	·552	·538	·525	·514	·503	·492	·481	·471	·462	·453	·444	·435	490
500	·576	·563	·549	·536	·524	·513	·502	·491	·481	·471	·462	·453	·444	500

TABLE II.—*continued.*

(Barometer at Sea Level, 30 inches.)

Height in Feet.	TEMPERATURE OF EXTERNAL AIR—DEGREES FAHRENHEIT.													Height in Feet.
	−20°	−10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	
510	·654	·637	·622	·608	·594	·581	·569	·557	·545	·534	·523	·513	·503	510
520	·666	·650	·634	·620	·606	·593	·580	·568	·556	·545	·533	·523	·513	520
530	·679	·662	·646	·631	·617	·604	·591	·578	·566	·555	·544	·533	·522	530
540	·691	·675	·658	·643	·629	·615	·602	·589	·577	·565	·554	·543	·532	540
550	·704	·687	·670	·655	·640	·626	·613	·600	·587	·575	·564	·553	·542	550
560	·717	·699	·683	·667	·652	·638	·624	·611	·598	·586	·574	·563	·552	560
570	·729	·712	·695	·679	·663	·649	·635	·622	·608	·596	·584	·573	·562	570
580	·742	·724	·707	·690	·675	·660	·646	·632	·619	·606	·595	·583	·571	580
590	·754	·737	·719	·702	·686	·672	·657	·643	·629	·617	·605	·593	·581	590
600	·767	·749	·731	·714	·698	·683	·668	·654	·640	·627	·615	·603	·591	600
610	·780	·761	·743	·726	·709	·694	·679	·665	·650	·637	·625	·613	·601	610
620	·792	·774	·755	·738	·721	·705	·690	·675	·661	·648	·635	·623	·611	620
630	·805	·786	·767	·749	·732	·717	·701	·686	·671	·658	·645	·633	·620	630
640	·817	·798	·779	·761	·744	·728	·712	·697	·682	·668	·655	·643	·630	640
650	·830	·811	·791	·773	·755	·739	·723	·708	·692	·679	·666	·653	·640	650
660	·843	·823	·803	·785	·767	·750	·734	·718	·703	·689	·676	·662	·650	660
670	·855	·835	·815	·797	·778	·761	·745	·729	·713	·699	·686	·672	·660	670
680	·868	·847	·827	·808	·790	·773	·756	·740	·724	·709	·696	·682	·669	680
690	·880	·860	·839	·820	·801	·784	·767	·750	·734	·720	·706	·692	·679	690
700	·893	·872	·851	·832	·813	·795	·778	·761	·745	·730	·716	·702	·689	700
710	·905	·884	·863	·844	·824	·806	·789	·772	·755	·740	·726	·712	·698	710
720	·918	·896	·875	·855	·836	·817	·800	·782	·766	·751	·736	·722	·708	720
730	·930	·909	·887	·867	·847	·829	·811	·793	·776	·761	·746	·732	·718	730
740	·943	·921	·899	·879	·859	·840	·822	·804	·787	·771	·756	·742	·728	740
750	·955	·933	·911	·891	·870	·851	·833	·815	·797	·782	·767	·752	·738	750
760	·968	·945	·922	·902	·881	·862	·843	·825	·808	·792	·777	·761	·747	760
770	·980	·957	·934	·914	·893	·873	·854	·836	·818	·802	·787	·771	·757	770
780	·993	·970	·946	·926	·904	·885	·865	·847	·829	·812	·797	·781	·767	780
790	1·005	·982	·958	·937	·916	·896	·876	·857	·839	·823	·807	·791	·776	790
800	1·018	·994	·970	·949	·927	·907	·887	·868	·850	·833	·817	·801	·786	800
810	1·030	1·006	·982	·961	·938	·918	·898	·878	·860	·843	·827	·811	·796	810
820	1·043	1·018	·994	·972	·950	·929	·909	·889	·871	·854	·837	·821	·805	820
830	1·055	1·031	1·006	·984	·961	·940	·920	·900	·881	·864	·847	·831	·815	830
840	1·068	1·043	1·018	·995	·973	·951	·931	·911	·892	·874	·857	·841	·825	840
850	1·080	1·055	1·030	1·007	·984	·962	·942	·922	·902	·885	·867	·851	·835	850
860	1·093	1·067	1·041	1·019	·995	·974	·952	·932	·913	·895	·877	·860	·844	860
870	1·105	1·079	1·053	1·030	1·007	·985	·963	·943	·923	·905	·887	·870	·854	870
880	1·118	1·092	1·065	1·042	1·018	·996	·974	·954	·934	·915	·897	·880	·864	880
890	1·130	1·104	1·077	1·053	1·030	1·007	·985	·964	·944	·926	·907	·890	·873	890
900	1·143	1·116	1·089	1·065	1·041	1·018	·996	·975	·955	·936	·917	·900	·883	900
910	1·155	1·128	1·101	1·077	1·052	1·029	1·007	·986	·965	·946	·927	·910	·893	910
920	1·168	1·140	1·113	1·088	1·064	1·040	1·018	·996	·976	·956	·937	·920	·902	920
930	1·180	1·152	1·125	1·100	1·075	1·051	1·029	1·007	·986	·967	·947	·929	·912	930
940	1·193	1·164	1·137	1·111	1·086	1·062	1·040	1·017	·997	·977	·957	·939	·921	940
950	1·205	1·177	1·149	1·123	1·098	1·074	1·051	1·028	1·007	·987	·967	·949	·931	950
960	1·217	1·189	1·160	1·135	1·109	1·085	1·061	1·039	1·017	·997	·977	·959	·941	960
970	1·230	1·201	1·172	1·146	1·120	1·096	1·072	1·049	1·028	1·007	·987	·969	·950	970
980	1·242	1·213	1·184	1·158	1·131	1·107	1·083	1·060	1·038	1·018	·997	·978	·960	980
990	1·255	1·225	1·196	1·169	1·143	1·118	1·094	1·070	1·049	1·028	1·007	·988	·969	990
1,000	1·267	1·237	1·208	1·181	1·154	1·129	1·105	1·081	1·059	1·038	1·017	·998	·979	1,000

TABLE II.—*continued.*

(Barometer at Sea Level, 27 inches.)

Height in Feet.	TEMPERATURE OF EXTERNAL AIR—DEGREES FAHRENHEIT.													Height in Feet.
	−20°	−10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	
510	·587	·574	·560	·547	·534	·523	·512	·501	·490	·480	·471	·462	·453	510
520	·599	·585	·571	·557	·545	·533	·522	·510	·500	·490	·480	·471	·462	520
530	·610	·596	·582	·568	·555	·543	·532	·520	·509	·499	·489	·480	·470	530
540	·622	·607	·593	·578	·566	·553	·542	·530	·519	·508	·498	·489	·479	540
550	·633	·619	·604	·589	·576	·564	·552	·540	·528	·518	·508	·498	·488	550
560	·644	·630	·614	·600	·586	·574	·561	·549	·538	·527	·517	·506	·497	560
570	·656	·641	·625	·610	·597	·584	·571	·559	·547	·536	·526	·515	·506	570
580	·667	·652	·636	·621	·607	·594	·581	·569	·557	·545	·535	·524	·514	580
590	·679	·663	·647	·631	·618	·604	·591	·578	·566	·555	·544	·533	·523	590
600	·690	·674	·658	·642	·628	·614	·601	·588	·576	·564	·553	·542	·532	600
610	·701	·685	·669	·653	·638	·624	·611	·598	·585	·573	·562	·551	·541	610
620	·713	·696	·680	·663	·649	·634	·621	·607	·595	·583	·571	·560	·550	620
630	·724	·707	·690	·674	·659	·644	·631	·617	·604	·592	·580	·569	·558	630
640	·736	·718	·701	·684	·669	·654	·641	·627	·614	·601	·589	·578	·567	640
650	·747	·730	·712	·695	·680	·665	·651	·637	·623	·611	·599	·587	·576	650
660	·758	·741	·723	·706	·690	·675	·660	·646	·633	·620	·608	·596	·585	660
670	·770	·752	·734	·716	·700	·685	·670	·656	·642	·629	·617	·605	·594	670
680	·781	·763	·744	·727	·710	·695	·680	·666	·652	·638	·626	·614	·602	680
690	·793	·774	·755	·737	·721	·705	·690	·675	·661	·648	·635	·623	·611	690
700	·804	·785	·766	·748	·731	·715	·700	·685	·671	·657	·644	·632	·620	700
710	·815	·796	·777	·758	·741	·725	·710	·695	·680	·666	·653	·641	·629	710
720	·827	·807	·787	·769	·752	·735	·720	·704	·690	·676	·662	·650	·637	720
730	·838	·818	·798	·779	·762	·745	·729	·714	·699	·685	·671	·659	·646	730
740	·849	·829	·809	·790	·772	·755	·739	·723	·709	·694	·680	·668	·655	740
750	·861	·840	·820	·800	·783	·766	·749	·733	·718	·704	·690	·677	·664	750
760	·872	·851	·830	·811	·793	·776	·759	·743	·727	·713	·699	·685	·672	760
770	·883	·862	·841	·821	·803	·786	·769	·752	·737	·722	·708	·694	·681	770
780	·894	·873	·852	·832	·813	·796	·778	·762	·746	·731	·717	·703	·690	780
790	·906	·884	·862	·842	·824	·806	·788	·771	·756	·741	·726	·712	·698	790
800	·917	·895	·873	·853	·834	·816	·798	·781	·765	·750	·735	·721	·707	800
810	·928	·906	·884	·863	·844	·826	·808	·791	·774	·759	·744	·730	·716	810
820	·939	·917	·894	·874	·855	·836	·818	·800	·784	·768	·753	·739	·724	820
830	·951	·928	·905	·884	·865	·846	·827	·810	·793	·778	·762	·747	·733	830
840	·962	·939	·916	·895	·875	·856	·837	·819	·803	·787	·771	·756	·742	840
850	·973	·950	·927	·905	·886	·866	·847	·829	·812	·796	·780	·765	·751	850
860	·984	·960	·937	·916	·896	·876	·857	·839	·821	·805	·789	·774	·759	860
870	·995	·971	·948	·926	·906	·886	·867	·848	·831	·814	·798	·783	·768	870
880	1·007	·982	·959	·937	·916	·896	·876	·858	·840	·824	·807	·791	·777	880
890	1·018	·993	·969	·947	·927	·906	·886	·867	·850	·833	·816	·800	·785	890
900	1·029	1·004	·980	·958	·937	·916	·896	·877	·859	·842	·825	·809	·794	900
910	1·040	1·015	·991	·968	·947	·926	·906	·887	·868	·851	·834	·818	·803	910
920	1·051	1·026	1·001	·979	·957	·936	·916	·896	·878	·860	·843	·827	·811	920
930	1·063	1·037	1·012	·989	·968	·946	·925	·906	·887	·870	·852	·836	·820	930
940	1·074	1·048	1·023	1·000	·978	·956	·935	·915	·897	·879	·861	·845	·829	940
950	1·085	1·059	1·034	1·010	·988	·966	·945	·925	·906	·888	·870	·854	·838	950
960	1·096	1·069	1·044	1·020	·998	·976	·955	·935	·915	·897	·879	·862	·846	960
970	1·107	1·080	1·055	1·031	1·008	·986	·965	·944	·925	·906	·888	·871	·855	970
980	1·119	1·091	1·066	1·041	1·019	·996	·974	·954	·934	·916	·897	·880	·864	980
990	1·130	1·102	1·076	1·052	1·029	1·006	·984	·963	·944	·925	·906	·889	·872	990
1,000	1·141	1·113	1·087	1·062	1·039	1·016	·994	·973	·953	·934	·915	·898	·881	1,000

TABLE II.—*continued.*

(Barometer at Sea Level, 30 inches.)

Height in Feet.	TEMPERATURE OF EXTERNAL AIR—DEGREES FAHRENHEIT.													Height in Feet.
	−20°	−10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	
1,010	1·279	1·249	1·220	1·192	1·165	1·140	1·116	1·092	1·069	1·048	1·027	1·008	0·989	1,010
1,020	1·292	1·261	1·232	1·204	1·177	1·151	1·127	1·102	1·080	1·058	1·037	1·018	0·908	1,020
1,030	1·304	1·273	1·243	1·215	1·188	1·162	1·137	1·113	1·090	1·069	1·047	1·027	1·008	1,030
1,040	1·317	1·285	1·255	1·227	1·199	1·173	1·148	1·123	1·101	1·079	1·057	1·037	1·017	1,040
1,050	1·329	1·298	1·267	1·238	1·211	1·184	1·159	1·134	1·111	1·089	1·067	1·047	1·027	1,050
1,060	1·341	1·310	1·279	1·250	1·222	1·195	1·170	1·145	1·121	1·099	1·077	1·057	1·037	1,060
1,070	1·354	1·322	1·291	1·261	1·233	1·206	1·181	1·155	1·132	1·109	1·087	1·067	1·046	1,070
1,080	1·366	1·334	1·302	1·273	1·244	1·217	1·191	1·166	1·142	1·120	1·097	1·076	1·056	1,080
1,090	1·379	1·346	1·314	1·284	1·256	1·228	1·202	1·176	1·153	1·130	1·107	1·086	1·065	1,090
1,100	1·391	1·358	1·326	1·296	1·267	1·239	1·213	1·187	1·163	1·140	1·117	1·096	1·075	1,100
1,110	1·403	1·370	1·338	1·307	1·278	1·250	1·224	1·198	1·173	1·150	1·127	1·106	1·085	1,110
1,120	1·416	1·382	1·350	1·319	1·289	1·261	1·235	1·208	1·184	1·160	1·137	1·115	1·094	1,120
1 130	1·428	1·394	1·361	1·330	1·301	1·272	1·245	1·219	1·194	1·170	1·147	1·125	1·104	1,130
1,140	1·440	1·406	1·373	1·342	1·312	1·283	1·256	1·229	1·204	1·180	1·157	1·135	1·113	1,140
1,150	1·453	1·418	1·385	1·353	1·323	1·294	1·267	1·240	1·215	1·191	1·167	1·145	1·123	1,150
1,160	1·465	1·430	1·397	1·365	1·334	1·305	1·278	1·251	1·225	1·201	1·177	1·154	1·133	1,160
1,170	1·477	1·442	1·409	1·376	1·345	1·316	1·289	1·261	1·235	1·211	1·187	1·164	1·142	1,170
1,180	1·489	1·454	1·420	1·388	1·357	1·327	1·299	1·272	1·245	1·221	1·197	1·174	1·152	1,180
1,190	1·502	1·466	1·432	1·399	1·368	1·338	1·310	1·282	1·256	1·231	1·207	1·183	1·161	1,190
1,200	1·514	1·478	1·444	1·411	1·379	1·349	1·321	1·293	1·266	1·241	1·217	1·193	1·171	1,200
1,210	1·526	1·490	1·456	1·422	1·390	1·360	1·332	1·303	1·276	1·251	1·227	1·203	1·180	1,210
1,220	1·539	1·502	1·467	1·434	1·401	1·371	1·342	1·314	1·287	1·261	1·237	1·212	1·100	1,220
1,230	1·551	1·514	1·479	1·445	1·413	1·382	1·353	1·324	1·297	1·271	1·247	1·222	1·109	1,230
1,240	1·563	1·526	1·491	1·457	1·424	1·393	1·364	1·335	1·307	1·281	1·257	1·232	1·209	1,240
1,250	1·576	1·538	1·502	1·468	1·435	1·404	1·374	1·345	1·317	1·291	1·266	1·242	1·218	1,250
1,260	1·588	1·550	1·514	1·479	1·446	1·415	1·385	1·356	1·328	1·302	1·276	1·251	1·228	1,260
1,270	1·600	1·562	1·526	1·491	1·457	1·426	1·396	1·366	1·338	1·312	1·286	1·261	1·237	1,270
1,280	1·612	1·574	1·538	1·502	1·469	1·437	1·407	1·377	1·348	1·322	1·296	1·271	1·247	1,280
1,290	1·625	1·586	1·549	1·514	1·480	1·448	1·417	1·387	1·359	1·332	1·306	1·280	1·256	1,290
1,300	1·637	1·598	1·561	1·525	1·491	1·459	1·428	1·398	1·369	1·342	1·316	1·290	1·266	1,300
1,310	1·649	1·610	1·573	1·536	1·502	1·470	1·439	1·408	1·379	1·352	1·326	1·300	1·275	1,310
1,320	1·661	1·622	1·584	1·548	1·513	1·481	1·449	1·419	1·390	1·362	1·336	1·309	1·285	1,320
1,330	1·674	1·634	1·596	1·559	1·525	1·492	1·460	1·429	1·400	1·372	1·346	1·319	1·294	1,330
1,340	1·686	1·646	1·608	1·571	1·536	1·503	1·471	1·440	1·410	1·382	1·356	1·329	1·304	1,340
1,350	1·698	1·658	1·620	1·582	1·547	1·514	1·482	1·450	1·420	1·393	1·366	1·339	1·313	1,350
1,360	1·710	1·669	1·631	1·593	1·558	1·524	1·492	1·461	1·431	1·403	1·375	1·348	1·323	1,360
1,370	1·722	1·681	1·643	1·605	1·569	1·535	1·503	1·471	1·441	1·413	1·385	1·358	1·332	1,370
1,380	1·735	1·693	1·655	1·616	1·581	1·546	1·514	1·482	1·451	1·423	1·395	1·368	1·342	1,380
1,390	1·747	1·705	1·666	1·628	1·592	1·557	1·524	1·492	1·462	1·433	1·405	1·377	1·351	1,390
1,400	1·759	1·717	1·678	1·639	1·603	1·568	1·535	1·503	1·472	1·443	1·415	1·387	1·361	1,400
1,410	1·771	1·729	1·690	1·650	1·614	1·579	1·546	1·513	1·482	1·453	1·425	·397	1·370	1,410
1,420	1·783	1·741	·701	1·662	1·625	1·590	1·556	1·524	1·492	1·463	1·435	·406	1·380	1,420
1,430	1·796	1·753	1·713	1·673	1·636	1·601	1·567	1·534	1·503	1·473	1·444	1·416	1·389	1,430
1,440	1·808	1·765	1·724	1·685	1·647	1·612	1·577	1·545	1·513	1·483	1·454	1·426	1·399	1,440
1,450	1·820	1·777	1·736	1·696	1·658	1·623	1·588	1·555	1·523	1·493	1·464	1·436	1·408	1,450
1,460	1·832	1·788	1·748	1·707	1·670	1·633	1·599	1·565	1·533	1·503	1·474	1·445	1·418	1,460
1,470	1·844	1·800	1·759	1·719	1·681	1·644	1·609	1·576	1·543	1·513	1·484	1·455	1·427	1,470
1,480	1·857	1·812	1·771	1·730	1·692	1·655	1·620	1·586	1·554	1·523	1·493	1·465	1·437	1,480
1,490	1·869	1·824	1·782	1·742	1·703	1·666	1·630	1·597	1·564	1·533	1·503	1·474	1·446	1,490
1,500	1·881	1·836	1·794	1·753	1·714	1·677	1·641	1·607	1·574	1·543	1·513	1·484	1·456	1,500

TABLE II.—*continued.*

(Barometer at Sea Level, 27 inches.)

Height in Feet.	TEMPERATURE OF EXTERNAL AIR—DEGREES FAHRENHEIT.													Height in Feet.
	−20°	−10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	
1,010	1·152	1·124	1·098	1·072	1·049	1·026	1·004	0·983	0·962	0·943	0·924	0·907	0·890	1,010
1,020	1·163	1·135	1·108	1·083	1·059	1·036	1·013	0·992	0·972	0·952	0·933	0·916	0·898	1,020
1,030	1·174	1·146	1·119	1·093	1·069	1·046	1·023	1·002	0·981	0·962	0·942	0·924	0·907	1,030
1,040	1·185	1·157	1·129	1·104	1·079	1·056	1·033	1·011	0·991	0·971	0·951	0·933	0·915	1,040
1,050	1·196	1·168	1·140	1·114	1·090	1·066	1·043	1·021	1·000	0·980	0·960	0·942	0·924	1,050
1,060	1·208	1·178	1·151	1·124	1·100	1·075	1·052	1·031	1·009	0·989	0·969	0·951	0·933	1,060
1,070	1·219	1·189	1·161	1·135	1·110	1·085	1·062	1·040	1·019	0·998	0·978	0·960	0·941	1,070
1,080	1·230	1·200	1·172	1·145	1·120	1·095	1·072	1·050	1·028	1·008	0·987	0·968	0·950	1,080
1,090	1·241	1·211	1·182	1·156	1·130	1·105	1·082	1·059	1·038	1·017	0·996	0·977	0·958	1,090
1,100	1·252	1·222	1·193	1·166	1·140	1·115	1·091	1·069	1·047	1·026	1·005	0·986	0·967	1,100
1,110	1·263	1·233	1·204	1·176	1·150	1·125	1·101	1·078	1·056	1·035	1·014	0·995	0·976	1,110
1,120	1·274	1·244	1·214	1·187	1·160	1·135	1·110	1·088	1·066	1·044	1·023	1·004	0·984	1,120
1,130	1·285	1·254	1·225	1·197	1·170	1·145	1·120	1·097	1·075	1·053	1·032	1·012	0·993	1,130
1,140	1·296	1·265	1·235	1·208	1·180	1·155	1·130	1·107	1·084	1·062	1·041	1·021	1·001	1,140
1,150	1·307	1·276	1·246	1·218	1·190	1·164	1·140	1·116	1·094	1·072	1·050	1·030	1·010	1,150
1,160	1·319	1·287	1·257	1·228	1·201	1·174	1·149	1·126	1·103	1·081	1·059	1·039	1·019	1,160
1,170	1·330	1·298	1·267	1·230	1·211	1·184	1·159	1·135	1·112	1·090	1·068	1·048	1·027	1,170
1,180	1·341	1·308	1·278	1·249	1·221	1·194	1·169	1·145	1·121	1·099	1·077	1·056	1·036	1,180
1,190	1·352	1·319	1·288	1·260	1·231	1·204	1·178	1·154	1·131	1·108	1·086	1·065	1·044	1,190
1,200	1·363	1·330	1·299	1·270	1·241	1·214	1·188	1·164	1·140	1·117	1·095	1·074	1·053	1,200
1,210	1·374	1·341	1·310	1·280	1·251	1·224	1·198	1·173	1·149	1·126	1·104	1·083	1·062	1,210
1,220	1·385	1·352	1·320	1·291	1·261	1·234	1·207	1·183	1·159	1·135	1·113	1·091	1·070	1,220
1,230	1·396	1·362	1·331	1·301	1·271	1·244	1·217	1·192	1·168	1·144	1·122	1·100	1·079	1,230
1,240	1·407	1·373	1·341	1·311	1·281	1·254	1·227	1·202	1·177	1·153	1·131	1·109	1·087	1,240
1,250	1·418	1·384	1·352	1·322	1·292	1·263	1·237	1·211	1·187	1·163	1·140	1·118	1·096	1,250
1,260	1·429	1·395	1·363	1·332	1·302	1·273	1·246	1·220	1·196	1·172	1·148	1·126	1·105	1,260
1,270	1·440	1·406	1·373	1·342	1·312	1·283	1·256	1·230	1·205	1·181	1·157	1·135	1·113	1,270
1,280	1·451	1·416	1·384	1·352	1·322	1·293	1·266	1·239	1·214	1·190	1·166	1·144	1·122	1,280
1,290	1·462	1·427	1·304	1·363	1·332	1·303	1·275	1·249	1·224	1·199	1·175	1·152	1·130	1,290
1,300	1·473	1·438	1·405	1·373	1·342	1·313	1·285	1·258	1·233	1·208	1·184	1·161	1·139	1,300
1,310	1·484	1·449	1·415	1·383	1·352	1·323	1·295	1·267	1·242	1·217	1·193	1·170	1·148	1,310
1,320	1·495	1·460	1·426	1·304	1·362	1·333	1·304	1·277	1·251	1·226	1·202	1·178	1·156	1,320
1,330	1·506	1·470	1·436	1·404	1·372	1·342	1·314	1·286	1·261	1·235	1·211	1·187	1·165	1,330
1,340	1·517	1·481	1·447	1·414	1·382	1·352	1·323	1·296	1·270	1·244	1·220	1·196	1·173	1,340
1,350	1·528	1·492	1·457	1·425	1·393	1·362	1·333	1·305	1·279	1·254	1·229	1·204	1·182	1,350
1,360	1·539	1·503	1·468	1·435	1·403	1·372	1·343	1·314	1·288	1·263	1·237	1·213	1·191	1,360
1,370	1·550	1·514	1·478	1·445	1·413	1·382	1·352	1·324	1·297	1·272	1·246	1·222	1·199	1,370
1,380	1·561	1·524	1·489	1·455	1·423	1·391	1·362	1·333	1·307	1·281	1·255	1·231	1·208	1,380
1,390	1·572	1·535	1·499	1·466	1·433	1·401	1·371	1·343	1·316	1·290	1·264	1·239	1·216	1,390
1,400	1·583	1·546	1·510	1·476	1·443	1·411	1·381	1·352	1·325	1·209	1·273	1·248	1·225	1,400
1,410	1·594	1·557	1·520	1·486	1·453	1·421	1·391	1·361	1·334	1·308	1·282	1·257	1·233	1,410
1,420	1·605	1·567	1·531	1·496	1·463	1·431	1·400	1·371	1·343	1·317	1·291	1·265	1·242	1,420
1,430	1·616	1·578	1·541	1·507	1·473	1·410	1·410	1·380	1·352	1·326	1·300	1·274	1·250	1,430
1,440	1·627	1·589	1·552	1·517	1·483	1·450	1·419	1·390	1·362	1·335	1·309	1·283	1·259	1,440
1,450	1·638	1·600	1·562	1·527	1·493	1·460	1·429	1·309	1·371	1·344	1·318	1·292	1·267	1,450
1,460	1·649	1·610	1·572	1·537	1·503	1·470	1·439	1·408	1·380	1·353	1·326	1·300	1·276	1,460
1,470	1·660	1·621	1·583	1·547	1·513	1·480	1·448	1·418	1·389	1·362	1·335	1·309	1·284	1,470
1,480	1·671	1·632	1·593	1·558	1·523	1·489	1·458	1·427	1·399	1·371	1·344	1·318	1·293	1,480
1,490	1·682	1·642	1·604	1·568	1·533	1·499	1·467	1·437	1·408	1·380	1·353	1·326	1·301	1,490
1,500	1·696	1·653	1·614	1·578	1·543	1·509	1·477	1·446	1·417	1·389	1·362	1·335	1·310	1,500

TABLE III.

Comparison of the Metric and English Barometer Scales.

(1 Metre = 39·37079 Inches.)

Milli-metres.	Tenths of a Millimetre. 0	1	2	3	4	5	6	7	8	9
	English Inches.									
705	27·756	27·760	27·764	27·768	27·772	27·776	27·780	27·784	27·788	27·792
6	·796	·800	·804	·808	·812	·815	·819	·823	·827	·831
7	·835	·839	·843	·847	·851	·855	·859	·863	·867	·871
8	·875	·878	·882	·886	·890	·894	·898	·902	·906	·910
9	27·914	27·918	27·922	27·926	27·930	27·934	27·938	27·941	27·945	27·949
710	27·953	27·957	27·961	27·965	27·969	27·973	27·977	27·981	27·985	27·989
1	27·993	27·997	28·001	28·004	28·008	28·012	28·016	28·020	28·024	28·028
2	28·032	28·036	·040	·044	·048	·052	·056	·060	·063	·067
3	·071	·075	·079	·083	·087	·091	·095	·099	·103	·107
4	28·111	28·115	28·119	28·123	28·126	28·130	28·134	28·138	28·142	28·146
715	28·150	28·154	28·158	28·162	28·166	28·170	28·174	28·178	28·182	28·186
6	·189	·193	·197	·201	·205	·209	·213	·217	·221	·225
7	·229	·233	·237	·241	·245	·249	·252	·256	·260	·264
8	·268	·272	·276	·280	·284	·288	·292	·296	·300	·304
9	28·308	28·312	28·315	28·319	28·323	28·327	28·331	28·335	28·339	28·343
720	28·347	28·351	28·355	28·359	28·363	28·367	28·371	28·375	28·378	28·382
1	·386	·390	·394	·398	·402	·406	·410	·414	·418	·422
2	·426	·430	·434	·438	·441	·445	·449	·453	·457	·461
3	·465	·469	·473	·477	·481	·485	·489	·493	·497	·501
4	28·504	28·508	28·512	28·516	28·520	28·524	28·528	28·532	28·536	28·540
725	28·544	28·548	28·552	28·556	28·560	28·564	28·567	28·571	28·575	28·579
6	·583	·587	·591	·595	·599	·603	·607	·611	·615	·619
7	·623	·627	·630	·634	·638	·642	·646	·650	·654	·658
8	·662	·666	·670	·674	·678	·682	·686	·689	·693	·697
9	28·701	28·705	28·709	28·713	28·717	28·721	28·725	28·729	28·733	28·737
730	28·741	28·745	28·749	28·752	28·756	28·760	28·764	28·768	28·772	28·776
1	·780	·784	·788	·792	·796	·800	·804	·808	·812	·815
2	·819	·823	·827	·831	·835	·839	·843	·847	·851	·855
3	·859	·863	·867	·871	·875	·878	·882	·886	·890	·894
4	28·898	28·902	28·906	28·910	28·914	28·918	28·922	28·926	28·930	28·934
735	28·938	28·941	28·945	28·949	28·953	28·957	28·961	28·965	28·969	28·973
6	28·977	28·981	28·985	28·989	28·993	28·997	29·001	29·004	29·008	29·012
7	29·016	29·020	29·024	29·028	29·032	29·036	·040	·044	·048	·052
8	·056	·060	·064	·067	·071	·075	·079	·083	·087	·091
9	29·095	29·099	29·103	29·107	29·111	29·115	29·119	29·123	29·127	29·130
740	29·134	29·138	29·142	29·146	29·150	29·154	29·158	29·162	29·166	29·170
1	·174	·178	·182	·186	·190	·193	·197	·201	·205	·209
2	·213	·217	·221	·225	·229	·233	·237	·241	·245	·249
3	·252	·256	·260	·264	·268	·272	·276	·280	·284	·288
4	29·292	29·296	29·300	29·304	29·308	29·312	29·315	29·319	29·323	29·327

TABLE III.—*continued.*

Comparison of the Metric and English Barometer Scales.

(1 Metre = 39·37079 Inches.)

Milli-metres.	Tenths of a Millimetre.									
	0	1	2	3	4	5	6	7	8	9
	English Inches.									
745	29·331	29·335	29·339	29·343	29·347	29·351	29·355	29·359	29·363	29·367
6	·371	·375	·378	·382	·386	·390	·394	·398	·402	·406
7	·410	·414	·418	·422	·426	·430	·434	·438	·441	·445
8	·449	·453	·457	·461	·465	·469	·473	·477	·481	·485
9	29·489	29·493	29·497	29·501	29·504	29·508	29·512	29·516	29·520	29·524
750	29·528	29·532	29·536	29·540	29·544	29·548	29·552	29·556	29·560	29·564
1	·567	·571	·575	·579	·583	·587	·591	·595	·599	·603
2	·607	·611	·615	·619	·623	·627	·630	·634	·638	·642
3	·646	·650	·654	·658	·662	·666	·670	·674	·678	·682
4	29·686	29·690	29·693	29·697	29·701	29·705	29·709	29·713	29·717	29·721
755	29·725	29·729	29·733	29·737	29·741	29·745	29·749	29·753	29·756	29·760
6	·764	·768	·772	·776	·780	·784	·788	·792	·796	·800
7	·804	·808	·812	·815	·819	·823	·827	·831	·835	·839
8	·843	·847	·851	·855	·859	·863	·867	·871	·875	·878
9	29·882	29·886	29·890	29·894	29·898	29·902	29·906	29·910	29·914	29·918
760	29·922	29·926	29·930	29·934	29·938	29·941	29·945	29·949	29·953	29·957
1	29·961	29·965	29·969	29·973	29·977	29·981	29·985	29·989	29·993	29·997
2	30·001	30·004	30·008	30·012	30·016	30·020	30·024	30·028	30·032	30·036
3	·040	·044	·048	·052	·056	·060	·064	·067	·071	·075
4	30·079	30·083	30·087	30·091	30·095	30·099	30·103	30·107	30·111	30·115
765	30·119	30·123	30·127	30·130	30·134	30·138	30·142	30·146	30·150	30·154
6	·158	·162	·166	·170	·174	·178	·182	·186	·190	·193
7	·197	·201	·205	·209	·213	·217	·221	·225	·229	·233
8	·237	·241	·245	·249	·253	·256	·260	·264	·268	·272
9	30·276	30·280	30·284	30·288	30·292	30·296	30·300	30·304	30·308	30·312
770	30·316	30·319	30·323	30·327	30·331	30·335	30·339	30·343	30·347	30·351
1	·355	·359	·363	·367	·371	·375	·379	·382	·386	·390
2	·394	·398	·402	·406	·410	·414	·418	·422	·426	·430
3	·434	·438	·441	·445	·449	·453	·457	·461	·465	·469
4	30·473	30·477	30·481	30·485	30·489	30·493	30·497	30·501	30·504	30·508
775	30·512	30·516	30·520	30·524	30·528	30·532	30·536	30·540	30·544	30·548
6	·552	·556	·560	·564	·567	·571	·575	·579	·583	·587
7	·591	·595	·599	·603	·607	·611	·615	·619	·623	·627
8	·630	·634	·638	·642	·646	·650	·654	·658	·662	·666
9	30·670	30·674	30·678	30·682	30·686	30·690	30·693	30·697	30·701	30·705
780	30·709	30·713	30·717	30·721	30·725	30·729	30·733	30·737	30·741	30·745
1	·749	·753	·756	·760	·764	·768	·772	·776	·780	·784
2	·788	·792	·796	·800	·804	·808	·812	·816	·819	·823
3	·827	·831	·835	·839	·843	·847	·851	·855	·859	·863
4	·867	·871	·875	·879	·882	·886	·890	·894	·898	·902
785	30·906	30·91	30·914	30·918	30·922	30·926	30·930	30·934	30·938	30·942

Parts.

Mill.	Inch.
1	0·0394
2	·0787
3	·1181
4	·1575
5	·1969
6	·2362
7	·2756
8	·3150
9	·3543
10	·3937

TABLE IV.

Comparison of the English and Metric Barometer Scales.

(1 inch = 25·39954 millimetres.)

English Inches and Tenths.	Hundredths of an Inch.									
	0	1	2	3	4	5	6	7	8	9
27·0	685·79	686·04	686·30	686·55	686·80	687·06	687·31	687·57	687·82	688·07
·1	688·33	688·58	688·84	689·09	689·34	689·60	689·85	690·11	690·36	690·61
·2	690·87	691·12	691·38	691·63	691·88	692·14	692·39	692·65	692·90	693·15
·3	693·41	693·66	693·92	694·17	694·42	694·68	694·93	695·19	695·44	695·69
·4	695·95	696·20	696·46	696·71	696·96	697·22	697·47	697·73	697·98	698·23
·5	698·49	698·74	699·00	699·25	699·50	699·76	700·01	700·27	700·52	700·77
·6	701·03	701·28	701·54	701·79	702·04	702·30	702·55	702·81	703·06	703·31
·7	703·57	703·82	704·08	704·33	704·58	704·84	705·09	705·35	705·60	705·85
·8	706·11	706·36	706·62	706·87	707·12	707·38	707·63	707·89	708·14	708·39
·9	708·65	708·90	709·16	709·41	709·66	709·92	710·17	710·43	710·68	710·93
28·0	711·19	711·44	711·70	711·95	712·20	712·46	712·71	712·97	713·22	713·47
·1	713·73	713·98	714·24	714·49	714·74	715·00	715·25	715·51	715·76	716·01
·2	716·27	716·52	716·78	717·03	717·28	717·54	717·79	718·04	718·30	718·55
·3	718·81	719·06	719·31	719·57	719·82	720·08	720·33	720·58	720·84	721·09
·4	721·35	721·60	721·85	722·11	722·36	722·62	722·87	723·12	723·38	723·63
·5	723·89	724·14	724·39	724·65	724·90	725·16	725·41	725·66	725·92	726·17
·6	726·43	726·68	726·93	727·19	727·44	727·70	727·95	728·20	728·46	728·71
·7	728·97	729·22	729·47	729·73	729·98	730·24	730·49	730·74	731·00	731·25
·8	731·51	731·76	732·01	732·27	732·52	732·78	733·03	733·28	733·54	733·79
·9	734·05	734·30	734·55	734·81	735·06	735·32	735·57	735·82	736·08	736·33
29·0	736·59	736·84	737·09	737·35	737·60	737·86	738·11	738·36	738·62	738·87
·1	739·13	739·38	739·63	739·89	740·14	740·40	740·65	740·90	741·16	741·41
·2	741·67	741·92	742·17	742·43	742·68	742·94	743·19	743·44	743·70	743·95
·3	744·21	744·46	744·71	744·97	745·22	745·48	745·73	745·98	746·24	746·49
·4	746·75	747·00	747·25	747·51	747·76	748·02	748·27	748·52	748·78	749·03
·5	749·29	749·54	749·79	750·05	750·30	750·56	750·81	751·06	751·32	751·57
·6	751·83	752·08	752·33	752·59	752·84	753·10	753·35	753·60	753·86	754·11
·7	754·37	754·62	754·87	755·13	755·38	755·64	755·89	756·14	756·40	756·65
·8	756·91	757·16	757·41	757·67	757·92	758·18	758·43	758·69	758·94	759·19
·9	759·45	759·70	759·95	760·21	760·46	760·72	760·97	761·22	761·48	761·73

TABLE IV.—*continued.*

Comparison of the English and Metric Barometer Scales.

(1 inch = 25·39954 millimetres.)

English Inches and Tenths.	Hundredths of an Inch.									
	0	1	2	3	4	5	6	7	8	9
30·0	761·99	762·24	762·49	762·75	763·00	763·26	763·51	763·76	764·02	764·27
·1	764·53	764·78	765·03	765·29	765·54	765·80	766·05	766·30	766·56	766·81
·2	767·07	767·32	767·57	767·83	768·08	768·34	768·59	768·84	769·10	769·35
·3	769·61	769·86	770·11	770·37	770·62	770·88	771·13	771·38	771·64	771·89
·4	772·15	772·40	772·65	772·91	773·16	773·42	773·67	773·92	774·18	774·43
·5	774·69	774·94	775·19	775·45	775·70	775·96	776·21	776·46	776·72	776·97
·6	777·23	777·48	777·73	777·99	778·24	778·50	778·75	779·00	779·26	779·51
·7	779·77	780·02	780·27	780·53	780·78	781·04	781·29	781·54	781·80	782·05
·8	782·31	782·56	782·81	783·07	783·32	783·58	783·83	784·08	784·34	784·59
·9	784·85	785·10	785·35	785·61	785·86	786·12	786·37	786·62	786·88	787·13
31·0	787·30	787·64	787·89	788·15	788·40	788·66	788·91	789·16	789·42	789·67
·1	789·93	790·18	790·43	790·69	790·94	791·20	791·45	791·70	791·96	792·21
·2	792·47	792·72	792·97	793·23	793·48	793·74	793·99	794·24	794·50	794·75
·3	795·01	795·26	795·51	795·77	796·02	796·28	796·53	796·78	797·04	797·29
·4	797·55	797·80	798·05	798·31	798·56	798·82	799·07	799·32	799·58	799·83

Inch.	Mill.
1	25·400
2	50·799
3	76·199
4	101·598
5	126·998
6	152·397
7	177·797
8	203·196
9	228·596
10	253·995

Thousandths of an Inch.								
1	2	3	4	5	6	7	8	9
0·03	0·05	0·08	0·10	0·13	0·15	0·18	0·20	0·23

TABLE V.

Comparison of the Old French and English Barometers.

(1 Paris Line = 0·088814 English Inch.)

French or Paris Lines.	Tenths of a Line.									
	0	1	2	3	4	5	6	7	8	9
25 inches.	Eng. in.	Eng. in.	Eng. in.	Eng. in.	Eng. in.	Eng. in.	Eng. in.	Eng. in.	Eng. in.	Eng. in.
300	26·644	26·653	26·662	26·671	26·680	26·689	26·697	26·706	26·715	26·724
301	26·733	26·742	26·751	26·760	26·769	26·777	26·786	26·795	26·804	26·813
302	26·822	26·831	26·840	26·848	26·857	26·866	26·875	26·884	26·893	26·902
303	26·911	26·920	26·928	26·937	26·946	26·955	26·964	26·973	26·982	26·991
304	26·999	27·008	27·017	27·026	27·035	27·044	27·053	27·062	27·071	27·079
305	27·088	27·097	27·106	27·115	27·124	27·133	27·142	27·150	27·159	27·168
306	27·177	27·186	27·195	27·204	27·213	27·221	27·230	27·239	27·248	27·257
307	27·266	27·275	27·284	27·293	27·301	27·310	27·319	27·328	27·337	27·346
308	27·355	27·364	27·372	27·381	27·390	27·399	27·408	27·417	27·426	27·435
309	27·444	27·452	27·461	27·470	27·479	27·488	27·497	27·506	27·515	27·523
310	27·532	27·541	27·550	27·559	27·568	27·577	27·586	27·595	27·603	27·612
311	27·621	27·630	27·639	27·648	27·657	27·666	27·674	27·683	27·692	27·701
26 inches.										
312	27·710	27·719	27·728	27·737	27·745	27·754	27·763	27·772	27·781	27·790
313	27·799	27·808	27·817	27·825	27·834	27·843	27·852	27·861	27·870	27·879
314	27·888	27·896	27·905	27·914	27·923	27·932	27·941	27·950	27·959	27·968
315	27·976	27·985	27·994	28·003	28·012	28·021	28·030	28·039	28·047	28·056
316	28·065	28·074	28·083	28·092	28·101	28·110	28·119	28·127	28·136	28·145
317	28·154	28·163	28·172	28·181	28·190	28·198	28·207	28·216	28·225	28·234
318	28·243	28·252	28·261	28·269	28·278	28·287	28·296	28·305	28·314	28·323
319	28·332	28·341	28·349	28·358	28·367	28·376	28·385	28·394	28·403	28·412
320	28·420	28·429	28·438	28·447	28·456	28·465	28·474	28·483	28·492	28·500
321	28·509	28·518	28·527	28·536	28·545	28·554	28·563	28·571	28·580	28·589
322	28·598	28·607	28·616	28·625	28·634	28·643	28·651	28·660	28·669	28·678
323	28·687	28·696	28·705	28·714	28·722	28·731	28·740	28·749	28·758	28·767
27 inches.										
324	28·776	28·785	28·793	28·802	28·811	28·820	28·829	28·838	28·847	28·856
325	28·865	28·873	28·882	28·891	28·900	28·909	28·918	28·927	28·936	28·944
326	28·953	28·962	28·971	28·980	28·989	28·998	29·007	29·016	29·024	29·033
327	29·042	29·051	29·060	29·069	29·078	29·087	29·095	29·104	29·113	29·122
328	29·131	29·140	29·149	22·158	29·167	29·175	29·184	29·193	29·202	29·211
329	29·220	29·229	29·238	29·246	29·255	29·264	29·273	29·282	29·201	29·300
330	29·309	29·318	29·326	29·335	29·344	29·353	29·362	29·371	29·380	29·389
331	29·397	29·406	29·415	29·424	29·433	29·442	29·451	29·460	29·468	29·477
332	29·486	29·495	29·504	29·513	29·522	29·531	29·540	29·548	29·557	29·566
333	29·575	29·584	29·593	29·602	29·611	29·619	29·628	29·637	29·646	29·655
334	29·664	29·673	29·682	29·691	29·699	29·708	29·717	29·726	29·735	29·744
335	29·753	29·762	29·770	29·779	29·788	29·797	29·806	29·815	29·824	29·833
28 inches.										
336	29·842	29·850	29·859	29·868	29·877	29·886	29·895	29·904	29·913	29·921
337	29·930	29·939	29·948	29·957	29·966	29·975	29·984	29·992	30·001	30·010
338	30·019	30·028	30·037	30·046	30·055	30·064	30·072	30·081	30·090	30·099
339	30·108	30·117	30·126	30·135	30·143	30·152	30·161	30·170	30·179	30·188

TABLE V.—*continued.*

Comparison of the Old French and English Barometers.

(1 Paris Line = 0·088814 English Inch.)

French or Paris Lines.	Tenths of a Line.									
	0	1	2	3	4	5	6	7	8	9
28 inches.	Eng. in.	Eng. in.	Eng. in.	Eng. in.	Eng. in.	Eng. in.	Eng. in.	Eng. in.	Eng. in.	Eng. in.
340	30·197	30·206	30·215	30·223	30·232	30·241	30·250	30·259	30·268	30·277
341	30·286	30·294	30·303	30·312	30·321	30·330	30·339	30·348	30·357	30·366
342	30·374	30·383	30·392	30·401	30·410	30·419	30·428	30·437	30·445	30·454
343	30·463	30·472	30·481	38·490	30·499	30·508	30·516	30·525	30·534	30·543
344	30·552	30·561	30·570	30·579	30·588	30·596	30·605	30·614	30·623	30·632
345	30·641	30·650	30·659	30·667	30·676	30·685	30·694	30·703	30·712	30·721
346	30·730	30·739	30·747	30·756	30·765	30·774	30·783	30·792	35·801	30·810
347	30·818	30·827	30·836	30·845	30·854	30·863	30·872	30·881	30·890	30·898
29 inches.										
348	30·907	30·916	30·925	30·934	30·943	30·952	30·961	30·969	30·978	30·987

Hundredths of a Line.								
1	2	3	4	5	6	7	8	9
·0009	·0018	·0027	·0036	·0044	·0053	·0062	·0071	·0080

TABLE VI.

Conversion of Centigrade Degrees into Degrees of Fahrenheit.

Centi-grade Degrees.	Tenths of Degrees. 0	1	2	3	4	5	6	7	8	9
° −39	−38·2	−38·4	−38·6	−38·7	−38·9	−39·1	−39·3	−39·5	−39·6	−39·8
38	36·4	36·6	36·8	36·9	37·1	37·3	37·5	37·7	37·8	38·0
37	34·6	34·8	35·0	35·1	35·3	35·5	35·7	35·9	36·0	36·2
36	32·8	33·0	33·2	33·3	33·5	33·7	33·9	34·1	34·2	34·4
35	31·0	31·2	31·4	31·5	31·7	31·9	32·1	32·3	32·4	32·6
34	29·2	29·4	29·6	29·7	29·9	30·1	30·3	30·5	30·6	30·8
33	27·4	27·6	27·8	27·9	28·1	28·3	28·5	28·7	28·8	29·0
32	25·6	25·8	26·0	26·1	26·3	26·5	26·7	26·9	27·0	27·2
31	23·8	24·0	24·2	24·3	24·5	24·7	24·9	25·1	25·2	25·4
30	22·0	22·2	22·4	22·5	22·7	22·9	23·1	23·3	23·4	23·6
29	20·2	20·4	20·6	20·7	20·9	21·1	21·3	21·5	21·6	21·8
28	18·4	18·6	18·8	18·9	19·1	19·3	19·5	19·7	19·8	20·0
27	16·6	16·8	17·0	17·1	17·3	17·5	17·7	17·9	18·0	18·2
26	14·8	15·0	15·2	15·3	15·5	15·7	15·9	16·1	16·2	16·4
25	13·0	13·2	13·4	13·5	13·7	13·9	14·1	14·3	14·4	14·6
24	11·2	11·4	11·6	11·7	11·9	12·1	12·3	12·5	12·6	12·8
23	9·4	9·6	9·8	9·9	10·1	10·3	10·5	10·7	10·8	11·0
22	7·6	7·8	8·0	8·1	8·3	8·5	8·7	8·9	9·0	9·2
21	5·8	6·0	6·2	6·3	6·5	6·7	6·9	7·1	7·2	7·4
20	4·0	4·2	4·4	4·5	4·7	4·9	5·1	5·3	5·4	5·6
19	2·2	2·4	2·6	2·7	2·9	3·1	3·3	3·5	3·6	3·8
18	−0·4	−0·6	−0·8	−0·9	−1·1	−1·3	−1·5	−1·7	−1·8	2·0
17	+1·4	+1·2	+1·0	+0·9	+0·7	+0·5	+0·3	+0·1	0·0	−0·2
16	3·2	3·0	2·8	2·7	2·5	2·3	2·1	1·9	+1·8	+1·6
15	5·0	4·8	4·6	4·5	4·3	4·1	3·9	3·7	3·6	3·4
14	6·8	6·6	6·4	6·3	6·1	5·9	5·7	5·5	5·4	5·2
13	8·6	8·4	8·2	8·1	7·9	7·7	7·5	7·3	7·2	7·0
12	10·4	10·2	10·0	9·9	9·7	9·5	9·3	9·1	9·0	8·8
11	12·2	12·0	11·8	11·7	11·5	11·3	11·1	10·9	10·8	10·6
10	14·0	13·8	13·6	13·5	13·3	13·1	12·9	12·7	12·6	12·4
9	15·8	15·6	15·4	15·3	15·1	14·9	14·7	14·5	14·4	14·2
8	17·6	17·4	17·2	17·1	16·9	16·7	16·5	16·3	16·2	16·0
7	19·4	19·2	19·0	18·9	18·7	18·5	18·3	18·1	18·0	17·8
6	21·2	21·0	20·8	20·7	20·5	20·3	20·1	19·9	19·8	19·6
5	23·0	22·8	22·6	22·5	22·3	22·1	21·9	21·7	21·6	21·4
4	24·8	24·6	24·4	24·3	24·1	23·9	23·7	23·5	23·4	23·2
3	26·6	26·4	26·2	26·1	25·9	25·7	25·5	25·3	25·2	25·0
2	28·4	28·2	28·0	27·9	27·7	27·5	27·3	27·1	27·0	26·8
1	30·2	30·0	29·8	29·7	29·5	29·3	29·1	28·9	28·8	28·6
−0	+32·0	+31·8	+31·6	+31·5	+31·3	+31·1	+30·9	+30·7	+30·6	+30·4

TABLE VI.—*continued.*

Conversion of Centigrade Degrees into Degrees of Fahrenheit.

Centigrade Degrees.	Tenths of Degrees.									
	0	1	2	3	4	5	6	7	8	9
°										
+ 0	+32·0	+32·2	+32·4	+32·5	+32·7	+32·9	+33·1	+33·3	+33·4	+33·6
1	33·8	34·0	34·2	34·3	34·5	34·7	34·9	35·1	35·2	35·4
2	35·6	35·8	36·0	36·1	36·3	36·5	36·7	36·9	37·0	37·2
3	37·4	37·6	37·8	37·9	38·1	38·3	38·5	38·7	38·8	39·0
4	39·2	39·4	39·6	39·7	39·9	40·1	40·3	40·5	40·6	40·8
5	41·0	41·2	41·4	41·5	41·7	41·9	42·1	42·3	42·4	42·6
6	42·8	43·0	43·2	43·3	43·5	43·7	43·9	44·1	44·2	44·4
7	44·6	44·8	45·0	45·1	45·3	45·5	45·7	45·9	46·0	46·2
8	46·4	46·6	46·8	46·9	47·1	47·3	47·5	47·7	47·8	48·0
9	48·2	48·4	48·6	48·7	48·9	49·1	49·3	49·5	49·6	49·8
10	50·0	50·2	50·4	50·5	50·7	50·9	51·1	51·3	51·4	51·6
11	51·8	52·0	52·2	52·3	52·5	52·7	52·9	53·1	53·2	53·4
12	53·6	53·8	54·0	54·1	54·3	54·5	54·7	54·9	55·0	55·2
13	55·4	55·6	55·8	55·9	56·1	56·3	56·5	56·7	56·8	57·0
14	57·2	57·4	57·6	57·7	57·9	58·1	58·3	58·5	58·6	58·8
15	59·0	59·2	59·4	59·5	59·7	59·9	60·1	60·3	60·4	60·6
16	60·8	61·0	61·2	61·3	61·5	61·7	61·9	62·1	62·2	62·4
17	62·6	62·8	63·0	63·1	63·3	63·5	63·7	63·9	64·0	64·2
18	64·4	64·6	64·8	64·9	65·1	65·3	65·5	65·7	65·8	66·0
19	66·2	66·4	66·6	66·7	66·9	67·1	67·3	67·5	67·6	67·8
20	68·0	68·2	68·4	68·5	68·7	68·9	69·1	69·3	69·4	69·6
21	69·8	70·0	70·2	70·3	70·5	70·7	70·9	71·1	71·2	71·4
22	71·6	71·8	72·0	72·1	72·3	72·5	72·7	72·9	73·0	73·2
23	73·4	73·6	73·8	73·9	74·1	74·3	74·5	74·7	74·8	75·0
24	75·2	75·4	75·6	75·7	75·9	76·1	76·3	76·5	76·6	76·8
25	77·0	77·2	77·4	77·5	77·7	77·9	78·1	78·3	78·4	78·6
26	78·8	79·0	79·2	79·3	79·5	79·7	79·9	80·1	80·2	80·4
27	80·6	80·8	81·0	81·1	81·3	81·5	81·7	81·9	82·0	82·2
28	82·4	82·6	82·8	82·9	83·1	83·3	83·5	83·7	83·8	84·0
29	84·2	84·4	84·6	84·7	84·9	85·1	85·3	85·5	85·6	85·8
30	86·0	86·2	86·4	86·5	86·7	86·9	87·1	87·3	87·4	87·6
31	87·8	88·0	88·2	88·3	88·5	88·7	88·9	89·1	89·2	89.4
32	89·6	89·8	90·0	90·1	90·3	90·5	90·7	90·9	91·0	91·2
33	91·4	91·6	91·8	91·9	92·1	92·3	92·5	92·7	92·8	93·0
34	93·2	93·4	93·6	93·7	93·9	94·1	94·3	94·5	94·6	94·8
35	95·0	95·2	95·4	95·5	95·7	95·9	96·1	96·3	96·4	96·6
36	96·8	97·0	97·2	97·3	97·5	97·7	97·9	98·1	98·2	98·4
37	98·6	98·8	99·0	99·1	99·3	99·5	99·7	99·9	100·0	100·2
38	100·4	100·6	100·8	100·9	101·1	101·3	101·5	101·7	101·8	102·0
+39	+102·2	+102·4	+102·6	+102·7	+102·9	+103·1	+103·3	+103·5	+103·6	+103·8

TABLE VII.

Conversion of Degrees of Fahrenheit into Centigrade Degrees.

Degrees of Fah.	Tenths of Degrees.									
	0	1	2	3	4	5	6	7	8	9
−36°	−37·8	−37·8	−37·9	−37·9	−38·0	−38·1	−38·1	−38·2	−38·	−37·7
35	37·2	37·3	37·3	37·4	37·4	37·5	37·6	37·6	37·7	38·3
34	36·7	36·7	36·8	36·8	36·9	36·9	37·0	37·1	37·1	37·2
33	36·1	36·2	36·2	36·3	36·3	36·4	36·4	36·5	36·6	36·6
32	35·6	35·6	35·7	35·7	35·8	35·8	35·9	35·9	36·0	36·1
31	35·0	35·1	35·1	35·2	35·2	35·3	35·3	35·4	35·4	35·5
30	34·4	34·5	34·6	34·6	34·7	34·7	34·8	34·8	34·9	34·9
29	33·9	33·9	34·0	34·1	34·1	34·2	34·2	34·3	34·3	34·4
28	33·3	33·4	33·4	33·5	33·6	33·6	33·7	33·7	33·8	33·8
27	32·8	32·8	32·9	32·9	33·0	33·1	33·1	33·2	33·2	33·3
26	32·2	32·3	32·3	32·4	32·4	32·5	32·6	32·6	32·7	32·7
25	31·7	31·7	31·8	31·8	31·9	31·9	32·0	32·1	32·1	32·2
24	31·1	31·2	31·2	31·3	31·3	31·4	31·4	31·5	31·6	31·6
23	30·6	30·6	30·7	30·7	30·8	30·8	30·9	30·9	31·0	31·1
22	30·0	30·1	30·1	30·2	30·2	30·3	30·3	30·4	30·4	30·5
21	29·4	29·5	29·6	29·6	29·7	29·7	29·8	29·8	29·9	29·9
20	28·9	28·9	29·0	29·1	29·1	29·2	29·2	29·3	29·3	29·4
19	28·3	28·4	28·4	28·5	28·6	28·6	28·7	28·7	28·8	28·8
18	27·8	27·8	27·9	27·9	28·0	28·1	28·1	28·2	28·2	28·3
17	27·2	27·3	27·3	27·4	27·4	27·5	27·6	27·6	27·7	27·7
16	26·7	26·7	26·8	26·8	26·9	26·9	27·0	27·1	27·1	27·2
15	26·1	26·2	26·2	26·3	26·3	26·4	26·4	26·5	26·6	26·6
14	25·6	25·6	25·7	25·7	25·8	25·8	25·9	25·9	26·0	26·1
13	25·0	25·1	25·1	25·2	25·2	25·3	25·3	25·4	25·4	25·5
12	24·4	24·5	24·6	24·6	24·7	24·7	24·8	24·8	24·9	24·9
11	23·9	23·9	24·0	24·1	24·1	24·2	24·2	24·3	24·3	24·4
10	23·3	23·4	23·4	23·5	23·6	23·6	23·7	23·7	23·8	23·8
9	22·8	22·8	22·9	22·9	23·0	23·1	23·1	23·2	23·2	23·3
8	22·2	22·3	22·3	22·4	22·4	22·5	22·6	22·6	22·7	22·7
7	21·7	21·7	21·8	21·8	21·9	21·9	22·0	22·1	22·1	22·2
6	21·1	21·2	21·2	21·3	21·3	21·4	21·4	21·5	21·6	21·6
5	20·6	20·6	20·7	20·7	20·8	20·8	20·9	20·9	21·0	21·1
4	20·0	20·1	20·1	20·2	20·2	20·3	20·3	20·4	20·4	20·5
3	19·4	19·5	19·6	19·6	19·7	19·7	19·8	19·8	19·9	19·9
2	18·9	18·9	19·0	19·1	19·1	19·2	19·2	19·3	19·3	19·4
1	18·3	18·4	18·4	18·5	18·6	18·6	18·7	18·7	18·8	18·8
−0	17·8	17·8	17·9	17·9	18·0	18·1	18·1	18·2	18·2	18·3
+0	17·8	17·7	17·7	17·6	17·6	17·5	17·4	17·4	17·3	17·3
1	17·2	17·2	17·1	17·1	17·0	16·9	16·9	16·8	16·8	16·7
2	16·7	16·6	16·6	16·5	16·4	16·4	16·3	16·3	16·2	16·2
3	16·1	16·1	16·0	15·9	15·9	15·8	15·8	15·7	15·7	15·6
+4	−15·6	−15·5	−15·4	−15·4	−15·3	−15·3	−15·2	−15·2	−15·1	−15·1

TABLE VII.—*continued.*

Conversion of Degrees of Fahrenheit into Centigrade Degrees.

Degrees of Fah.	Tenths of Degrees.									
	0	1	2	3	4	5	6	7	8	9
+5	−15·0	−14·9	−14·9	−14·8	−14·8	−14·7	−14·7	−14·6	−14·6	−14·5
6	14·4	14·4	14·3	14·3	14·2	14·2	14·1	14·1	14·0	13·9
7	13·9	13·8	13·8	13·7	13·7	13·6	13·6	13·5	13·4	13·4
8	13·3	13·3	13·2	13·2	13·1	13·1	13·0	12·9	12·9	12·8
9	12·8	12·7	12·7	12·6	12·6	12·5	12·4	12·4	12·3	12·3
10	12·2	12·2	12·1	12·1	12·0	11·9	11·9	11·8	11·8	11·7
11	11·7	11·6	11·6	11·5	11·4	11·4	11·3	11·3	11·2	11·2
12	11·1	11·1	11·0	10·9	10·9	10·8	10·8	10·7	10·7	10·6
13	10·6	10·5	10·4	10·4	10·3	10·3	10·2	10·2	10·1	10·1
14	10·0	9·9	9·9	9·8	9·8	9·7	9·7	9·6	9·6	9·5
15	9·4	9·4	9·3	9·3	9·2	9·2	9·1	9·1	9·0	8·9
16	8·9	8·8	8·8	8·7	8·7	8·6	8·6	8·5	8·4	8·4
17	8·3	8·3	8·2	8·2	8·1	8·1	8·0	7·9	7·9	7·8
18	7·8	7·7	7·7	7·6	7·6	7·5	7·4	7·4	7·3	7·3
19	7·2	7·2	7·1	7·1	7·0	6·9	6·9	6·8	6·8	6·7
20	6·7	6·6	6·6	6·5	6·4	6·4	6·3	6·3	6·2	6·2
21	6·1	6·1	6·0	5·9	5·9	5·8	5·8	5·7	5·7	5·6
22	5·6	5·5	5·4	5·4	5·3	5·3	5·2	5·2	5·1	5·1
23	5·0	4·9	4·9	4·8	4·8	4·7	4·7	4·6	4·6	4·5
24	4·4	4·4	4·3	4·3	4·2	4·2	4·1	4·1	4·0	3·9
25	3·9	3·8	3·8	3·7	3·7	3·6	3·6	3·5	3·4	3·4
26	3·3	3·3	3·2	3·2	3·1	3·1	3·0	2·9	2·9	2·8
27	2·8	2·7	2·7	2·6	2·6	2·5	2·4	2·4	2·3	2·3
28	2·2	2·2	2·1	2·1	2·0	1·9	1·9	1·8	1·8	1·7
29	1·7	1·6	1·6	1·5	1·4	1·4	1·3	1·3	1·2	1·2
30	1·1	1·1	1·0	0·9	0·9	0·8	0·8	0·7	0·7	0·6
31	−0·6	−0·5	−0·4	−0·4	−0·3	−0·3	−0·2	−0·2	−0·1	−0·1
32	+0·0	+0·1	+0·1	+0·2	+0·2	+0·3	+0·3	+0·4	+0·4	+0·5
33	0·6	0·6	0·7	0·7	0·8	0·8	0·9	0·9	1·0	1·1
34	1·1	1·2	1·2	1·3	1·3	1·4	1·4	1·5	1·6	1·6
35	1·7	1·7	1·8	1·8	1·9	1·9	2·0	2·1	2·1	2·2
36	2·2	2·3	2·3	2·4	2·4	2·5	2·6	2·6	2·7	2·7
37	2·8	2·8	2·9	2·9	3·0	3·1	3·1	3·2	3·2	3·3
38	3·3	3·4	3·4	3·5	3·6	3·6	3·7	3·7	3·8	3·8
39	3·9	3·9	4·0	4·1	4·1	4·2	4·2	4·3	4·3	4·4
40	4·4	4·5	4·6	4·6	4·7	4·7	4·8	4·8	4·9	4·9
41	5·0	5·1	5·1	5·2	5·2	5·3	5·3	5·4	5·4	5·5
42	5·6	5·6	5·7	5·7	5·8	5·8	5·	5·9	6·0	6·1
43	6·1	6·2	6·2	6·3	6·3	6·4	6·4	6·5	6·6	6·6
44	6·7	6·7	6·8	6·8	6·9	6·9	7·0	7·1	7·1	7·2
45	7·2	7·3	7·3	7·4	7·4	7·5	7·6	7·6	7·7	7·7
46	7·8	7·8	7·9	7·9	8·0	8·1	8·1	8·2	8·2	8·3
47	8·3	8·4	8·4	8·5	8·6	8·6	8·7	8·7	8·8	8·8
48	8·9	8·9	9·0	9·1	9·1	9·2	9·2	9·3	9·3	9·4
+49	+9·4	+9·5	+9·6	+9·6	+9·7	+9·7	+9·8	+9·8	+9·9	+9·9

TABLE VII.—*continued.*

Conversion of Degrees of Fahrenheit into Centigrade Degrees.

Degrees of Fah.	Tenths of Degrees.									
	0	1	2	3	4	5	6	7	8	9
+50°	+10·0	+10·1	+10·1	+10·2	+10·2	+10·3	+10·3	+10·4	+10·4	+10·5
51	10·6	10·6	10·7	10·7	10·8	10·8	10·9	10·9	11·0	11·1
52	11·1	11·2	11·2	11·3	11·3	11·4	11·4	11·5	11·6	11·6
53	11·7	11·7	11·8	11·8	11·9	11·9	12·0	12·1	12·1	12·2
54	12·2	12·3	12·3	12·4	12·4	12·5	12·6	12·6	12·7	12·7
55	12·8	12·8	12·9	12·9	13·0	13·1	13·1	13·2	13·2	13·3
56	13·3	13·4	13·4	13·5	13·6	13·6	13·7	13·7	13·8	13·8
57	13·9	13·9	14·0	14·1	14·1	14·2	14·2	14·3	14·3	14·4
58	14·4	14·5	14·6	14·6	14·7	14·7	14·8	14·8	14·9	14·9
59	15·0	15·1	15·1	15·2	15·2	15·3	15·3	15·4	15·4	15·5
60	15·6	15·6	15·7	15·7	15·8	15·8	15·9	15·9	16·0	16·1
61	16·1	16·2	16·2	16·3	16·3	16·4	16·4	16·5	16·6	16·6
62	16·7	16·7	16·8	16·8	16·9	16·9	17·0	17·1	17·1	17·2
63	17·2	17·3	17·3	17·4	17·4	17·5	17·6	17·6	17·7	17·7
64	17·8	17·8	17·9	17·9	18·0	18·1	18·1	18·2	18·2	18·3
65	18·3	18·4	18·4	18·5	18·6	18·6	18·7	18·7	18·8	18·8
66	18·9	18·9	19·0	19·1	19·1	19·2	19·2	19·3	19·3	19·4
67	19·4	19·5	19·6	19·6	19·7	19·7	19·8	19·8	19·9	19·9
68	20·0	20·1	20·1	20·2	20·2	20·3	20·3	20·4	20·4	20·5
69	20·6	20·6	20·7	20·7	20·8	20·8	20·9	20·9	21·0	21·1
70	21·1	21·2	21·2	21·3	21·3	21·4	21·4	21·5	21·6	21·6
71	21·7	21·7	21·8	21·8	21·9	21·9	22·0	22·1	22·1	22·2
72	22·2	22·3	22·3	22·4	22·4	22·5	22·6	22·6	22·7	22·7
73	22·8	22·8	22·9	22·9	23·0	23·1	23·1	23·2	23·2	23·3
74	23·3	23·4	23·4	23·5	23·6	23·6	23·7	23·7	23·8	23·8
75	23·9	23·9	24·0	24·1	24·1	24·2	24·2	24·3	24·3	24·4
76	24·4	24·5	24·6	24·6	24·7	24·7	24·8	24·8	24·9	24·9
77	25·0	25·1	25·1	25·2	25·2	25·3	25·3	25·4	25·4	25·5
78	25·6	25·6	25·7	25·7	25·8	25·8	25·9	25·9	26·0	26·1
79	26·1	26·2	26·2	26·3	26·3	26·4	26·4	26·5	26·6	26·6
80	26·7	26·7	26·8	26·8	26·9	26·9	27·0	27·1	27·1	27·2
81	27·2	27·3	27·3	27·4	27·4	27·5	27·6	27·6	27·7	27·7
82	27·8	27·8	27·9	27·9	28·0	28·1	28·1	28·2	28·2	28·3
83	28·3	28·4	28·4	28·5	28·6	28·6	28·7	28·7	28·8	28·8
84	28·9	28·9	29·0	29·1	29·1	29·2	29·2	29·3	29·3	29·4
85	29·4	29·5	29·6	29·6	29·7	29·7	29·8	29·8	29·9	29·9
86	30·0	30·1	30·1	30·2	30·2	30·3	30·3	30·4	30·4	30·5
87	30·6	30·6	30·7	30·7	30·8	30·8	30·9	30·9	31·0	31·1
88	31·1	31·2	31·2	31·3	31·3	31·4	31·4	31·5	31·6	31·6
89	31·7	31·7	31·8	31·8	31·9	31·9	32·0	32·1	32·1	33·2
90	32·2	32·3	32·3	32·4	32·4	32·5	32·6	32·6	32·7	32·7
91	32·8	32·8	32·9	32·9	33·0	33·1	33·1	33·2	33·2	33·3
92	33·3	33·4	33·4	33·5	33·6	33·6	33·7	33·7	33·8	33·8
93	33·9	33·9	34·0	34·1	34·1	34·2	34·2	34·3	34·8	34·4
+94	+34·4	+34·5	+34·6	+34·6	+34·7	+34·7	+34·8	+34·8	+34·9	+34·9

TABLE VII.—*continued.*

Conversion of Degrees of Fahrenheit into Centigrade Degrees.

Degrees of Fah.	Tenths of Degrees.									
	0	1	2	3	4	5	6	7	8	9
+97°	+35·0	+35·1	+35·1	+35·2	+35·2	+35·3	+35·3	+35·4	+35·4	+35·5
95	35·6	35·6	35·7	35·7	35·8	35·8	35·9	35·9	36·0	36·1
96	36·1	36·2	36·2	36·3	36·3	36·4	36·4	36·5	36·6	36·6
98	36·7	36·7	36·8	36·8	36·9	36·9	37·0	37·1	37·1	37·2
99	37·2	37·3	37·3	37·4	37·4	37·5	37·6	37·6	37·7	37·7
100	37·8	37·8	37·9	37·9	38·0	38·1	38·1	38·2	38·2	38·3
101	38·3	38·4	38·4	38·5	38·6	38·6	38·7	38·7	38·8	38·8
102	38·9	38·9	39·0	39·1	39·1	39·2	39·2	39·3	39·3	39·4
103	39·4	39·5	39·6	39·6	39·7	39·7	39·8	39·8	39·9	39·9
104	40·0	40·1	40·1	40·2	40·2	40·3	40·3	40·4	40·4	40·5
105	40·6	40·6	40·7	40·7	40·8	40·8	40·9	40·9	41·0	41·1
106	41·1	41·2	41·2	41·3	41·3	41·4	41·4	41·5	41·6	41·6
107	41·7	41·7	41·8	41·8	41·9	41·9	42·0	42·1	42·1	42·2
108	42·2	42·3	42·3	42·4	42·4	42·5	42·6	42·6	42·7	42·7
109	42·8	42·8	42·9	42·9	43·0	43·1	43·1	43·2	43·2	43·3
110	43·3	43·4	43·4	43·5	43·6	43·6	43·7	43·7	43·8	43·8
111	43·9	43·9	44·0	44·1	44·1	44·2	44·2	44·3	44·3	44·4
112	44·4	44·5	44·6	44·6	44·7	44·7	44·8	44·8	44·9	44·9
113	45·0	45·1	45·1	45·2	45·2	45·3	45·3	45·4	45·4	45·5
114	45·6	45·6	45·7	45·7	45·8	45·8	45·9	45·9	46·0	46·1
115	46·1	46·2	46·2	46·3	46·3	46·4	46·4	46·5	46·6	46·6
116	46·7	46·7	46·8	46·8	46·9	46·9	47·0	47·1	47·1	47·2
117	47·2	47·3	47·3	47·4	47·4	47·5	47·6	47·6	47·7	47·7
118	47·8	47·8	47·9	47·9	48·0	48·1	48·1	48·2	48·2	48·3
119	48·3	48·4	48·4	48·5	48·6	48·6	48·7	48·7	48·8	48·8
120	48·9	48·9	48·9	49·1	49·1	49·2	49·2	49·3	49·3	49·4
121	49·4	49·5	49·6	49·6	49·7	49·7	49·8	49·8	49·9	49·9
+122	+50·0	+50·1	+50·1	+50·2	+50·2	+50·3	+50·3	+50·4	+50·4	+50·5

TABLE VIII.

Conversion of Degrees of Reaumur into Degrees of Fahrenheit.

Degrees of Reaumur.	Tenths of Degrees.									
	0	1	2	3	4	5	6	7	8	9
° −39	−55·8	−56·0	−56·2	−56·4	−56·7	−56·9	−57·1	−57·3	−57·6	−57·8
38	53·5	53·7	54·0	54·2	54·4	54·6	54·9	55·1	55·3	55·5
37	51·3	51·5	51·7	51·9	52·2	52·4	52·6	52·8	53·1	53·3
36	49·0	49·2	49·5	49·7	49·9	50·1	50·4	50·6	50·8	51·0
35	46·8	47·0	47·2	47·4	47·7	47·9	48·1	48·3	48·6	48·8
34	44·5	44·7	45·0	45·2	45·4	45·6	45·9	46·1	46·3	46·5
33	42·3	42·5	42·7	42·9	43·2	43·4	43·6	43·8	44·1	44·3
32	40·0	40·2	40·5	40·7	40·9	41·1	41·4	41·6	41·8	42·0
31	37·8	38·0	38·2	38·4	38·7	38·9	39·1	39·3	39·6	39·8
30	35·5	35·7	36·0	36·2	36·4	36·6	36·9	37·1	37·3	37·5
29	33·3	33·5	33·7	33·9	34·2	34·4	34·6	34·8	35·1	35·3
28	31·0	31·2	31·5	31·7	31·9	32·1	32·4	32·6	32·8	33·0
27	28·8	29·0	29·2	29·4	29·7	29·9	30·1	30·3	30·6	30·8
26	26·5	26·7	27·0	27·2	27·4	27·6	27·9	28·1	28·3	28·5
25	24·3	24·5	24·7	24·9	25·2	25·4	25·6	25·8	26·1	26·3
24	22·0	22·2	22·5	22·7	22·9	23·1	23·4	23·6	23·8	24·0
23	19·8	20·0	20·2	20·4	20·7	20·9	21·1	21·3	21·6	21·8
22	17·5	17·7	18·0	18·2	18·4	18·6	18·9	19·1	19·3	19·5
21	15·3	15·5	15·7	15·9	16·2	16·4	16·6	16·8	17·1	17·3
20	13·0	13·2	13·5	13·7	13·9	14·1	14·4	14·6	14·8	15·0
19	10·8	11·0	11·2	11·4	11·7	11·9	12.1	12·3	12·6	12·8
18	8·5	8·7	9·0	9·2	9·4	9·6	9·9	10·1	10·3	10·5
17	6·3	6·5	6·7	6·9	7·2	7·4	7·6	7·8	8·1	8·3
16	4·0	4·2	4·5	4·7	4·9	5·1	5·4	5·6	5·8	6·0
15	− 1·8	− 2·0	− 2·2	2·4	2·7	2·9	3·1	3·3	3·6	3·8
14	+ 0·5	+ 0·3	+ 0·1	− 0·2	− 0·4	− 0·6	− 0·9	− 1·1	− 1·3	− 1·5
13	2·8	2·5	2·3	+ 2·1	+ 1·9	+ 1·6	+ 1·4	+ 1·2	+ 1·0	+ 0·7
12	5·0	4·8	4·6	4·3	4·1	3·9	3·7	3·4	3·2	3·0
11	7·3	7·0	6·8	6·6	6·4	6·1	5·9	5·7	5·5	5·2
10	9·5	9·5	9·1	8·8	8·6	8·4	8·2	7·9	7·7	7·5
9	11·8	11·5	11·3	11·1	10·9	10·6	10·4	10·2	10·0	9·7
8	14·0	13·8	13·6	13·3	13·1	12·9	12·7	12·4	12·2	12·0
7	16·3	16·0	15·8	15·6	15·4	15·1	14·9	14·7	14·5	14·2
6	18·5	18·3	18·1	17·8	17·6	17·4	17·2	16·9	16·7	16·5
5	20·8	20·5	20·3	20·1	19·9	19·6	19·4	19·2	19·0	18·7
4	23·0	22·8	22·6	22·3	22·1	21·9	21·7	21·4	21·2	21·0
3	25·3	25·0	24·8	24·6	24·4	24·1	23·9	23·7	23·5	23·2
2	27·5	27·3	27·1	26·8	26·6	26·4	26·2	25·9	25·7	25·5
1	29·8	29·5	29·3	29·1	28·9	28·6	28·4	28·2	28·0	27·7
− 0	32·0	31·8	31·6	31·3	31·1	30·9	30·7	30·4	30·2	30·0
+ 0	32·0	32·2	32·5	32·7	32·9	33·1	33·4	33·6	33·8	34·0
1	34·3	34·5	34·7	34·9	35·2	35·4	35·6	35·8	36·1	36·3
2	36·5	36·7	37·0	37·2	37·4	37·6	37·9	38·1	38·3	38·5
3	38·8	39·0	39·2	39·4	39·7	39·9	40·1	40·3	40·6	40·8
+ 4	+41·0	+41·2	+41·5	+41·7	+41·9	+42·1	+42·4	+42·6	+42·8	+43·0

TABLE VIII.—*continued.*

Conversion of Degrees of Reaumur into Degrees of Fahrenheit.

Degrees of Reaumur.	Tenths of Degrees.									
	0	1	2	3	4	5	6	7	8	9
°										
+5	+43·3	+43·5	+43·7	+43·9	+44·2	+44·4	+44·6	+44·8	+45·1	+45·3
6	45·5	45·7	46·0	46·2	46·4	46·6	46·9	47·1	47·3	47·5
7	47·8	48·0	48·2	48·4	48·7	48·9	49·1	49·3	49·6	49·8
8	50·0	50·2	50·5	50·7	50·9	51·1	51·4	51·6	51·8	52·0
9	52·3	52·5	52·7	52·9	53·2	53·4	53·6	53·8	54·1	54·3
10	54·5	54·7	55·0	55·2	55·4	55·6	55·9	56·1	56·3	56·5
11	56·8	57·0	57·2	57·4	57·7	57·9	58·1	58·3	58·6	58·8
12	59·0	59·2	59·5	59·7	59·9	60·1	60·4	60·6	60·8	61·0
13	61·3	61·5	61·7	61·9	62·2	62·4	62·6	62·8	63·1	63·3
14	63·5	63·7	64·0	64·2	64·4	64·6	64·9	65·1	65·3	65·5
15	65·8	66·0	66·2	66·4	66·7	66·9	67·1	67·3	67·6	67·8
16	68·0	68·2	68·5	68·7	68·9	69·1	69·4	69·6	69·8	70·0
17	70·3	70·5	70·7	70·9	71·2	71·4	71·6	71·8	72·1	72·3
18	72·5	72·7	73·0	73·2	73·4	73·6	73·9	74·1	74·3	74·5
19	74·8	75·0	75·2	75·4	75·7	75·9	76·1	76·3	76·6	76·7
20	77·0	77·2	77·5	77·7	77·9	78·1	78·4	78·6	78·8	79·0
21	79·3	79·5	79·7	79·9	80·2	80·4	80·6	80·8	81·1	81·3
22	81·5	81·7	82·0	82·2	82·4	82·6	82·9	83·1	83·3	83·5
23	83·8	84·0	84·2	84·4	84·7	84·9	85·1	85·3	85·6	85·8
24	86·0	86·2	86·5	86·7	86·9	87·1	87·4	87·6	87·8	88·0
25	88·3	88·5	88·7	88·9	89·2	89·4	89·6	89·8	90·1	90·3
26	90·5	90·7	91·0	91·2	91·4	91·6	91·9	92·1	92·3	92·5
27	92·8	93·0	93·2	93·4	93·7	93·9	94·1	94·3	94·6	94·7
28	95·0	95·2	95·5	95·7	95·9	96·1	96·4	96·6	96·8	97·0
29	97·3	97·5	97·7	97·9	98·2	98·4	98·6	98·8	99·1	99·3
30	99·5	99·7	100·0	100·2	100·4	100·6	100·9	101·1	101·3	101·5
31	101·8	102·0	102·2	102·4	102·7	102·9	103·1	103·3	103·6	103·8
32	104·0	104·2	104·5	104·7	104·9	105·1	105·4	105·6	105·8	106·0
33	106·3	106·5	106·7	106·9	107·2	107·4	107·6	107·8	108·1	108·3
34	108·5	108·7	109·0	109·2	109·4	109·6	109·9	110·1	110·3	110·5
35	110·8	111·0	111·2	111·4	111·7	111·9	112·1	112·3	112·6	112·8
36	113·0	113·2	113·5	113·7	113·9	114·1	114·4	114·6	114·8	115·0
37	115·3	115·5	115·7	115·9	116·2	116·4	116·6	116·8	117·1	117·3
38	117·5	117·7	118·0	118·2	118·4	118·6	118·9	119·1	119·3	119·5
+39	+119·8	+120·0	+120·2	+120·4	+120·7	+120·9	+121·1	+121·3	+121·6	+121·8

TABLE IX.—Rainfall Table.

Conversion of Millimetres to English Inches.

(1 Millimetre = 0·03938203 inch.)

Millimetres.	Equivalent in English Inches.	Millimetres.	Equivalent in English Inches.	Millimetres.	Equivalent in English Inches.	Millimetres.	Equivalent in English Inches.	Millimetres.	Equivalent in English Inches.	Millimetres.	Equivalent in English Inches.
0	0·000	40	1·575	80	3·151	120	4·726	160	6·301	200	7·876
1	0·039	41	1·615	81	3·190	121	4·765	161	6·341	201	7·916
2	0·079	42	1·654	82	3·228	122	4·805	162	6·380	202	7·955
3	0·118	43	1·693	83	3·269	123	4·844	163	6·419	203	7·995
4	0·158	44	1·733	84	3·308	124	4·883	164	6·459	204	8·034
5	0·197	45	1·772	85	3·347	125	4·923	165	6·498	205	8·073
6	0·236	46	1·812	86	3·387	126	4·962	166	6·537	206	8·113
7	0·276	47	1·851	87	3·426	127	5·002	167	6·577	207	8·152
8	0·315	48	1·890	88	3·466	128	5·041	168	6·616	208	8·191
9	0·354	49	1·930	89	3·505	129	5·080	169	6·656	209	8·231
10	0·394	50	1·969	90	3·544	130	5·120	170	6·695	210	8·270
11	0·433	51	2·008	91	3·584	131	5·159	171	6·734	211	8·310
12	0.473	52	2·048	92	3·623	132	5·198	172	6·774	212	8·349
13	0·512	53	2·087	93	3·663	133	5·238	173	6·813	213	8·388
14	0·551	54	2·127	94	3·702	134	5·277	174	6·852	214	8·428
15	0·591	55	2·166	95	3·741	135	5·317	175	6·892	215	8·467
16	0·630	56	2·205	96	3·781	136	5·356	176	6·931	216	8·507
17	0·669	57	2·245	97	3·820	137	5·395	177	6·971	217	8·546
18	0·709	58	2·284	98	3·859	138	5·435	178	7·010	218	8·585
19	0·748	59	2·324	99	3·899	139	5·474	179	7·040	219	8·625
20	0·787	60	2·363	100	3·938	140	5·513	180	7·080	220	8·664
21	0·827	61	2·402	101	3·978	141	5·553	181	7·128	221	8·703
22	0·866	62	2·442	102	4·017	142	5·592	182	7·167	222	8·743
23	0·906	63	2·481	103	4·056	143	5·632	183	7·207	223	8·782
24	0·945	64	2·520	104	4·096	144	5·671	184	7·246	224	8·822
25	0·985	65	2·560	105	4·135	145	5·710	185	7·286	225	8·861
26	1·024	66	2·599	106	4·174	146	5·750	186	7·325	226	8·900
27	1·063	67	2·639	107	4·214	147	5·789	187	7·364	227	8·940
28	1·103	68	2·678	108	4·253	148	5·829	188	7·404	228	8·979
29	1·142	69	2·717	109	4·293	149	5·868	189	7·443	229	9·018
30	1·181	70	2·757	110	4·332	150	5·907	190	7·483	230	9·058
31	1.221	71	2·796	111	4·371	151	5·947	191	7·522	231	9·097
32	1·260	72	2·836	112	4·411	152	5·986	192	7·561	232	9·137
33	1·300	73	2·875	113	4·450	153	6·025	193	7·601	233	9·176
34	1·339	74	2·914	114	4·490	154	6·065	194	7·640	234	9·215
35	1·378	75	2·954	115	4·529	155	6·104	195	7·679	235	9·255
36	1·418	76	2·993	116	4·568	156	6·144	196	7·719	236	9·294
37	1·457	77	3·032	117	4·608	157	6·183	197	7·758	237	9·334
38	1·497	78	3·072	118	4·647	158	6·222	198	7·798	238	9·372
39	1·536	79	3·111	119	4·686	159	6·262	199	7·837	239	9·412
										240	9·452

TABLE X.—Rainfall Table.

Conversion of English Inches and Tenths to Millimetres.

(1 inch = $25 \cdot 39\dot{2}$ millimetres.)

English Inches.	Tenths of an Inch.									
	0	1	2	3	4	5	6	7	8	9
0	0·0	2·5	5·1	7·6	10·2	12·7	15·2	17·8	20·3	22·9
1	25·4	27·9	30·5	33·0	35·6	38·1	40·6	43·2	45·7	48·2
2	50·8	53·3	55·9	58·4	60·9	63·5	66·0	68·6	71·1	73·6
3	76·2	78·7	81·3	83·8	86·3	88·9	91·4	94·0	96·5	99·0
4	101·6	104·1	106·6	109·2	111·7	114·3	116·8	119·3	121·9	124·4
5	127·0	129·5	132·0	134·6	137·1	139·7	142·2	144·7	147·3	149·8
6	152·4	154·9	157·4	160·0	162·5	165·0	167·6	170·1	172·7	175·2
7	177·7	180·3	182·8	185·4	187·9	190·4	193·0	195·5	198·1	200·6
8	203·1	205·7	208·2	210·8	213·3	215·8	218·4	220·9	223·5	226·0
9	228·5	231·1	233·6	236·1	238·7	241·2	243·8	246·3	248·8	251·4
10	253·9	256·5	259·0	261·5	264·1	266·6	269·2	271·7	274·2	276·8
11	279·3	281·9	284·4	286·9	289·5	292·0	294·5	297·1	299·6	302·2
12	304·7	307·2	309·8	312·3	314·9	317·4	319·9	322·5	325·0	327·6
13	330·1	332·6	335·2	337·7	340·3	342·8	345·3	347·9	350·4	353·0
14	355·5	358·0	360·6	363·1	365·6	368·2	370·7	373·3	375·8	378·3
15	380·9	383·4	386·0	388·5	391·0	393·6	396·1	398·7	401·2	403·7
16	406·3	408·8	411·4	413·9	416·4	419·0	421·5	424·0	426·6	429·1
17	431·7	434·2	436·7	439·3	441·8	444·4	446·9	449·4	452·0	454·5
18	457·1	459·6	462·1	464·7	467·2	469·8	472·3	474·8	477·4	479·9
19	482·5	485·0	487·5	490·1	492·6	495·1	497·7	500·2	502·8	505·3
20	507·8	510·4	512·9	515·5	518·0	520·5	523·1	525·6	528·2	530·7
	0	1	2	3	4	5	6	7	8	9

Hundredths of an Inch.

1	2	3	4	5	6	7	8	9
0·25	0·51	0·76	1·02	1·27	1·52	1·78	2·03	2·29

APPENDIX III.

CIRCULAR addressed to VOLUNTEER OBSERVERS in connexion with the METEOROLOGICAL OFFICE.

Meteorological Office, 116, Victoria Street, S.W.,
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DEAR SIR,

IT has been resolved by the Meteorological Committee to make a commencement of publication of Data from other stations besides their Self-recording Observatories.

I have therefore been looking specially into the observations which are furnished to this Office by various volunteer observers, and in so doing have examined carefully those so kindly supplied by you.

I find it will be necessary, before attempting to publish any results, to obtain a more detailed statement as to the position of your instruments, and your method of observing them, than has hitherto been supplied to us, and for this purpose I venture to request you to fill up the accompanying form, and return it to me at your earliest convenience.

At the end of the form you will find some notes specially applicable to your own observations, to which I invite your kind attention.

On your returning this form filled up I shall forward a card containing the necessary corrections for facilitating the reduction of the Barometrical Readings to 32° F. and to Mean Sea Level, and I must request you to use this table, in preference to any other, in order to ensure absolute uniformity in the methods of reduction.

Yours very faithfully,

Director.

To____________________

NOTES

As to the Instruments employed, and their Exposure at ____________________

Barometer.

Is the tube enclosed in a frame-work of brass?
What is the maker's name?
Has it been compared with any recognised standard?
If so, give a copy of the correction certificate in the following Form.

No. of Instrument and Maker's Name.	Corrections at							Where and when Compared.
	27·5	28·0	28·5	29·0	29·5	30·0	30·5	

Is the instrument suspended in a good light? but beyond the reach of Solar rays? or any very sudden change of temperature?

Does it hang quite freely, so as to be perfectly vertical?

Have you any reason to suppose the instrument to be "sluggish," or otherwise defective?

What is the height of the cistern above the Mean Sea Level? and how was the value obtained?

Thermometers.

Have those in use been compared with any recognised Standard?
If so, give a copy of their corrections below.

No. of Instrument.	Corrections at							Where, and when Compared.
	32°	42°	52°	62°	72°	82°	92°	
Dry bulb -								
Wet bulb -								
Maximum -								
Minimum -								
Solar Radiation								
Terrestrial do.								

At what height above the ground are the instruments placed?
On, or in, what form of screen are the shaded thermometers exposed?

(*Note.*—If the name of the screen is not known, give a sketch and description of it.)

Have you a Solar Radiation Thermometer (*blackened bulb in vacuo*)?
If so, how is it exposed? and at what height from the ground?

At what hour* do you set your Maximum and Minimum Thermometers?
Give a rough plan of the enclosure in which the thermometers are exposed. marking the heights of the surrounding walls, fences, or trees; and showing where the instruments are placed.

Rain Gauge.

What form of gauge is in use?
If the name is not known, give a rough sketch of it.
What is the diameter of the funnel?
What is the height of the rim { above the ground? / " Mean Sea Level?
Should the gauge be on the roof of any building, be good enough to note the height of the rim above the roof.
Is the ground about your station level?
If not, say in what directions, and to about what extent, it slopes.

Wind.

How are the direction and force obtained?
Is the direction *true*, as distinguished from *magnetic*?
Is the force estimated by the Beaufort Scale, 0–12?
If an anemometer is used, describe its size and construction, and say how it is exposed.

Clouds.

According to what system do you classify the *form* of clouds?
Is the *amount* estimated by the scale, "0 = quite clear, 10 = entirely overcast?"

[In giving the direction of clouds the point *whence* they are moving should be recorded.]

Weather.

Is this recorded by the Beaufort scale, viz.:—b. blue sky; c. detached clouds; d. drizzling rain; f. fog; g. dark, gloomy; h. hail; l. lightning; m. misty (hazy); o. overcast; p. passing showers; q. squally; r. rain; s. snow; t. thunder; u. ugly, threatening; v. visibility, unusual transparency w. dew?

Special Notes with respect to the Observations already received

from________________________

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* At the Vienna Congress it was decided that these instruments should be read at the latest observing hour of the day, and the observations put down to the day on which they are taken.

APPENDIX IV.

THE following List of Works of Reference may be useful, although it necessarily excludes a great number of Treatises on Meteorology:

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